MECHANICAL DRAWING

OUTLINE OF COURSE ENGINEERING 3*a*, HARVARD UNIVERSITY

1908-09

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Special acknowledgment is due Professor G. C. ANTHONY, whose text book, "Mechanical Drawing," has suggested several of the exercises and problems given in these notes.

PLATE 1—GENERAL INSTRUCTIONS

USE OF MATERIALS—METHOD OF LAYING OUT DRAWING SHEET

LECTURE DATE.....

USE OF MATERIALS

A. **Pencil.**

(*a*) **6 H** pencil sharpened, on sand paper pad, to a *chisel* point. (Fig. 1.)

Used for *Laying out sheets* and *Blocking out drawings*.

(*b*) **2 H** pencil sharpened, on pad, to a *round* point. (Fig. 2.)

Used for *Pointing off distances*, *Strengthening outlines*, and *Lettering*.

(*c*) **Compass** pencil sharpened on outside. (Fig. 3.)

Use **6 H** for Blocking out; **2 H** for Strengthening.

Use end **A** of Needle Point in other leg of compasses. (Fig. 4.)

When radius is large bend the legs of compasses. (Fig. 5.)

B. **T-Square.***

(*a*) Always use **T**-square at *left* end of board. (Fig. 6.)

If left-handed, change to right end.

(*b*) Always draw along *upper* edge of **T**-square.

C. **Triangles.***

(*a*) Always use triangles on *upper* edge of **T**-square. (Fig. 6.)

Wherever possible draw with light coming from Direction (**L**).

(*b*) To draw *Parallel* lines, slide triangle along some Straight Edge (either **T**-square or another triangle). (Fig. 7.)

(*c*) To draw a *Perpendicular* to a given line. (Fig. 8.) Place a triangle along the given line, **A B**, as shown in *full lines* and bring some Straight Edge against the triangle; then turn triangle to *dotted* position, slide it along to required point and draw the perpendicular **C D**.

* Whenever possible draw the lines from **Left** to **Right** and from **Bottom** towards **Top** of sheet.

METHOD OF LAYING OUT DRAWING SHEET

I. Fold and cut sheet into four equal parts.

The kind of paper used in this course is known as "**Duplex**."

II. Thumb tack one part to Drawing Board. (One thumb tack in each corner.)

III. (Fig. 9.) With **T**-square laid across corners draw *short, light* lines, **AB** and **CD**, thus finding approximate centre of sheet. (**Use 6 H Pencil.**)

IV. (Fig. 10.) With **T**-square draw **EF** (*light*) through centre. With *Triangle* draw **GH**. These are called "**Centre Lines**" of sheet.

V. (Fig. 11.) Along *Centre Lines* lay off **9** inches horizontally and **6** inches vertically, each side of centre. (Measure with *Triangular Scale* as shown.) With **T**-square and Triangle draw rectangle, 18 inches by 12 inches, as shown. This is called the "**Cutting Line.**"

VI. (Fig. 12.) Again, lay off 8 inches and 5 inches on Centre Lines and complete second rectangle. This is called the "**Border Line.**"

VII. (Fig. 13.) The result is a sheet as shown; **18** inches by **12** inches (*outside measurement*) with **1** inch Border all around.

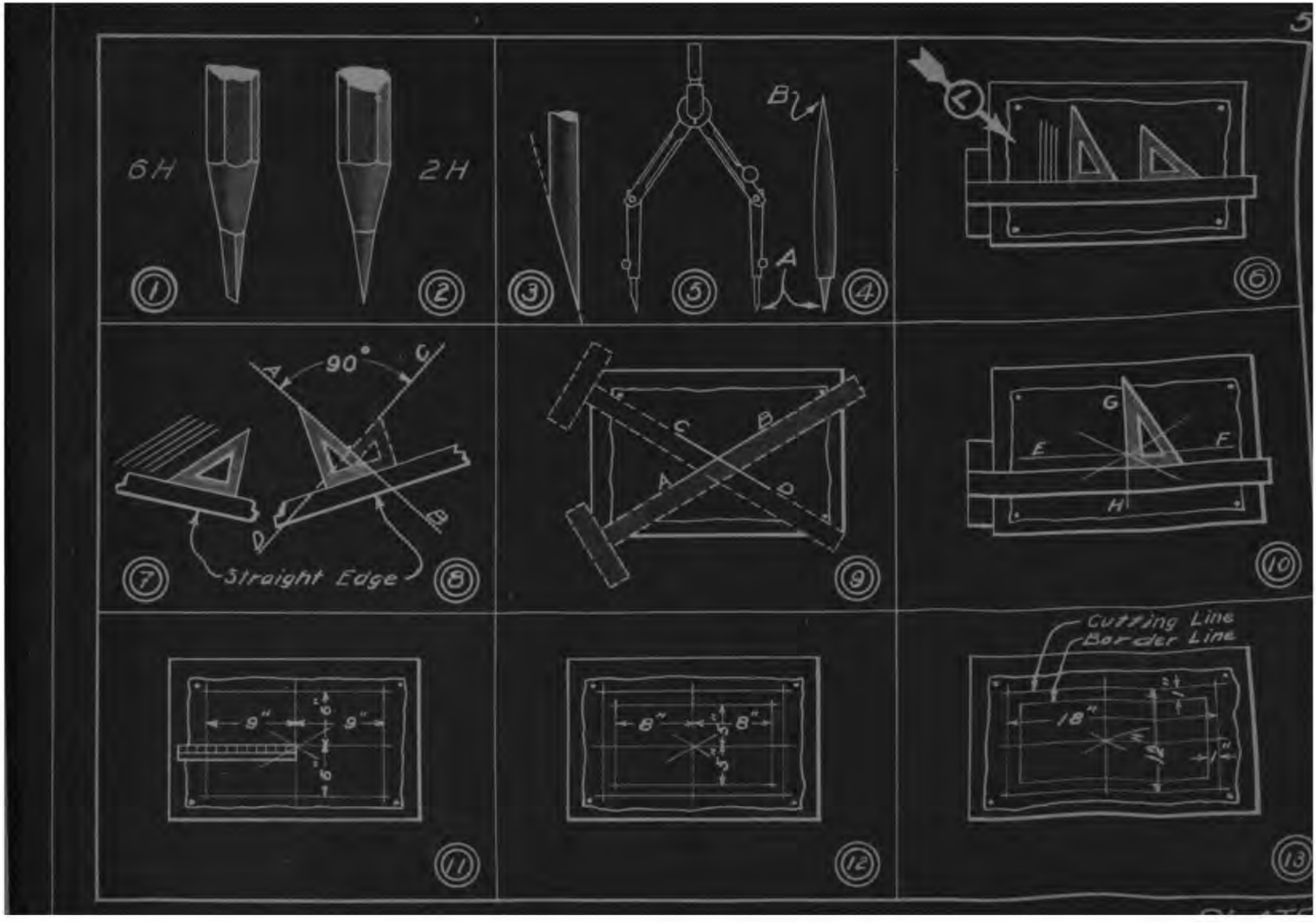

6H
2H
1
2
3
5
B
A
4
7
90°
C
A
B
Straight Edge
8
C
B
A
D
9
G
E
F
H
10
9"
9"
11
8"
8"
12
Cutting Line
Border Line
18"
1"
1"
13

PLATE 2 — PRACTICE IN PENCILING — LETTERING

LECTURE DATE.....

PLATE 2—PRACTICE IN PENCILING—LETTERING

I. All statements and dimensions enclosed in *rectangles* on the blue prints are to be omitted from the drawing sheets. They are for directions only.

The numerical dimensions given on the blue prints may not always agree with the "scale" (proportion) or with the exact arrangement shown. In such cases follow the stated *dimensions* rather than the *scale* of the drawing. This is the general rule in reading working drawings.

II. Lay out a sheet as explained on Pages 4 and 5.

III. Draw "guide lines" for letters *very lightly*.

(*a*) *Horizontal* lines (to show height of letters) are spaced accurately as shown by dimensions on blue print. Use triangular scale. (See Note **B**.)

(*b*) *Oblique* lines (to preserve uniform slant) are drawn at intervals with **30°** Triangle.

In pointing off distances, use **2 H** pencil with *round point*. (See Page 5, Fig. 2.)

For drawing guide lines use **6 H** pencil with *chisel point*. (See Page 5, Fig. 1.)

IV. Draw *freehand* the letters and figures indicated on opposite page. (Use **2 H** Pencil.)

This page shows arrangement only. Consult Page 107 for accurate form of letters.

(*a*) Press lightly.

(*b*) Make letters *round* and *full*.

(*c*) Avoid crowding.

(*d*) In common fractions, denominator figures should rest on Base Line.

V. Add Title.

(*a*) Draw Base Line for title $\frac{1}{2}$ inch below Border Line.

(*b*) Begin title far enough to the left to end exactly under (**A**).

To do this, determine length of title by blocking it out on another paper, or on margin outside of Cutting Line.

VI. Trim the sheet along the Cutting Line before handing it in.

Note A. STYLE OF LETTERING.

The lettering used in this course is an adaptation of the "Reinhardt" Gothic Alphabet. See "*Lettering*" by Charles W. Reinhardt.

Note B. HEIGHT OF LETTERS AND FIGURES.

(1) **Large Standard:**—

Lower case letters	$= \frac{1}{8}$ inch high.
Capitals and figures	$= \frac{3}{16}$ inch "
Common fractions (numerator and denominator each)	$= \frac{1}{8}$ inch "

(2) **Small standard:**—

Lower case letters	$= \frac{1}{10}$ inch high.
Capitals and figures	$= \frac{3}{20}$ inch "
Fractions (each term)	$= \frac{1}{10}$ inch "

It will be noticed that both standards follow the same *proportions* (Capitals = $\frac{3}{5}$ of lower case, etc.). The actual height used varies in practice. In this course, until further notice, the *larger standard* will be used.

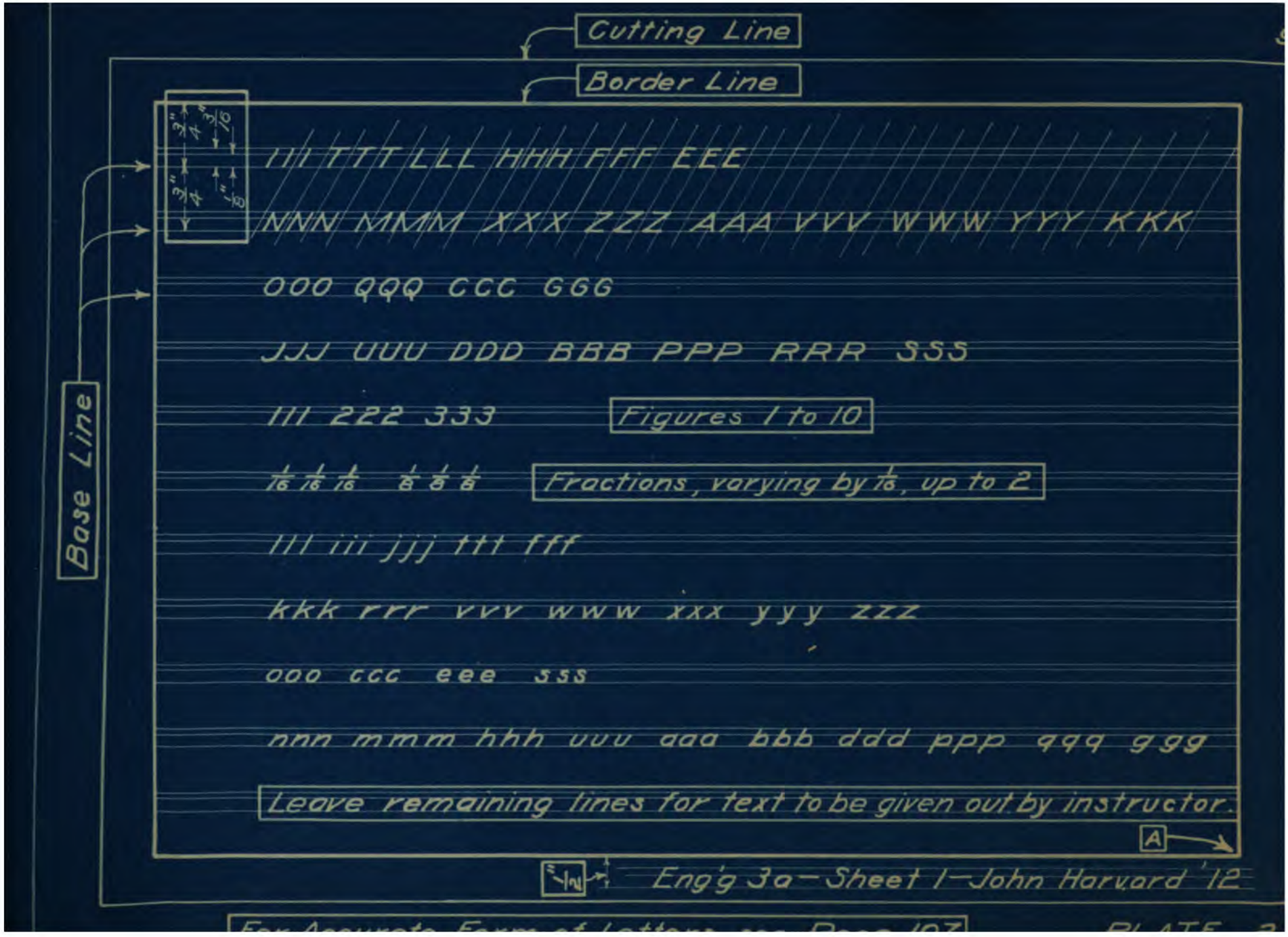

Cutting Line
Border Line
Base Line
3/4"
3/16"
3/4"
1/8"
IIII TTTT LLL HHHH FFF EEE
NNN MMMM XXX ZZZ AAA VVV WWW YYY KKK
OOO QQQ CCC GGG
JJJ UUU DDD BBB PPP RRR SSS
III 222 333
Figures 1 to 10
1/16 1/16 1/16 1/8 1/8 1/8
Fractions, varying by 1/16, up to 2
lll iii jjj ttt fff
kkk rrr vvv www xxx yyy zzz
ooo ccc eee sss
nnn mmm hhh uuu aaa bbb ddd ppp qqq ggg
Leave remaining lines for text to be given out by instructor.
A
1/2"
Eng'g 3a – Sheet 1 – John Harvard '12

PLATE 3 — PRACTICE IN PENCILING — STRAIGHT LINES

LECTURE DATE.....

PLATE 3—PRACTICE IN PENCILING—STRAIGHT LINES

I. Lines to be:—

(*a*) **Fine.**

(*b*) **Uniform.**

(*c*) **Accurately drawn.**

For lines use **6 H** pencil, sharpened to *chisel* point, as shown by Page 5, Fig. 1.

II. Ex. 1. **Horizontal Lines.**

(*a*) Lay scale along *vertical* Centre Line of sheet and point off spacing distances.

Use **2 H** pencil with *round point* and make very *light dots*.

(*b*) In drawing lines begin at *top* of sheet and work *downward*. (Use **T**-square.)

Vertical Lines.

(*a*) Point off distances along *horizontal* Centre Line of sheet.

(*b*) In drawing lines begin at *left* and work *toward the right*. (Use Triangle on upper edge of **T**-square.)

III. Ex. 2. **Parallel Slanting Lines.**

(*a*) Draw Parallelogram **A B C D.**

(*b*) *Outside* draw lines parallel to **A B.**

(*c*) *Inside* draw lines parallel to **B C.**

For method of drawing parallel lines see Page 4-C-b.

IV. Ex. 3. **Parallel Lines at 45°.**

Use 45° triangle on **T**-square.

Space points ¼ inch horizontally and vertically.

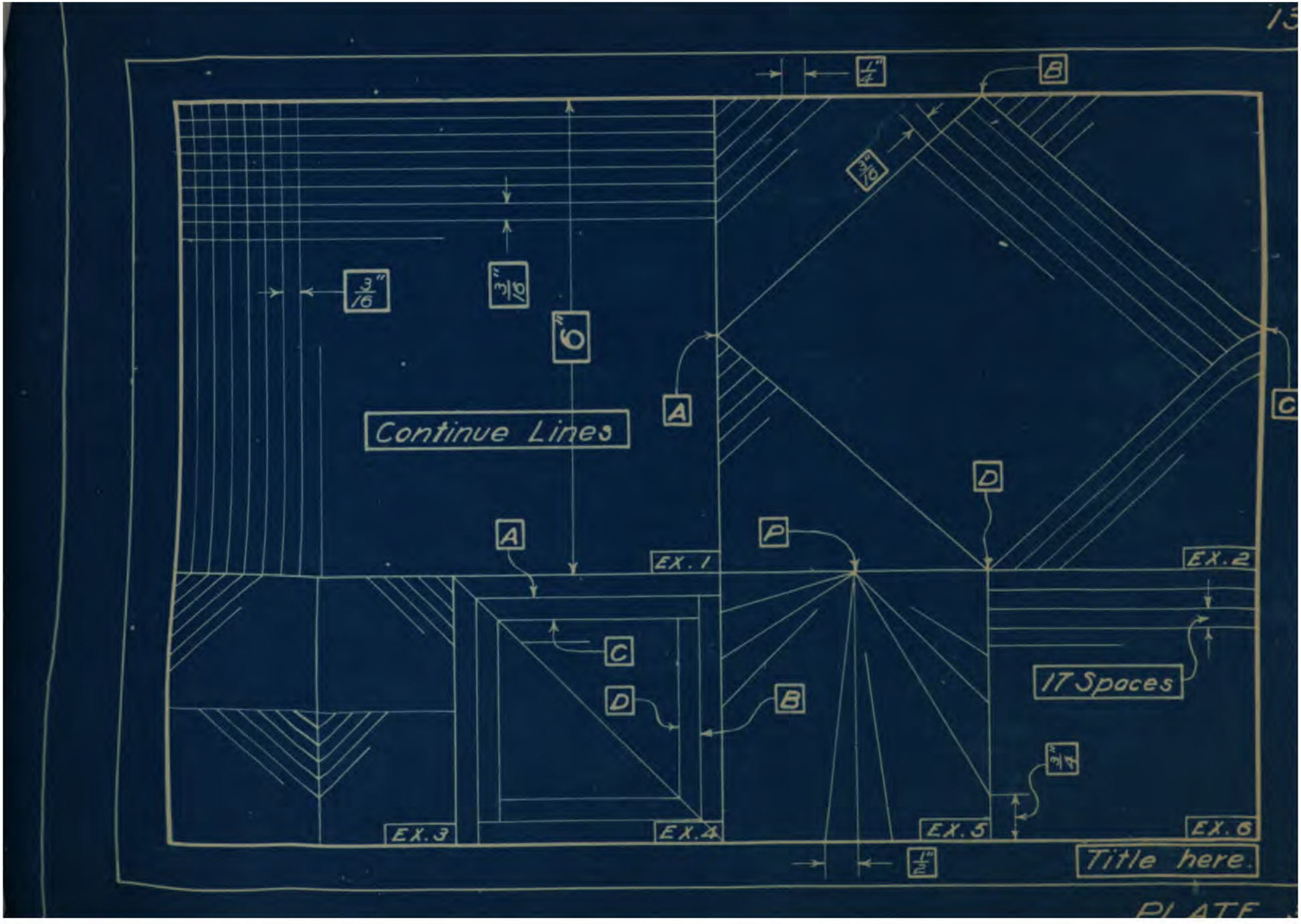
V. Ex. 4. Space lines ¼ inch apart.

First draw diagonal; then draw lines in order, **A, B, C, D,** etc.

VI. Ex. 5. Space points as indicated. Point **P** bisects top of square.

VII. Ex. 6. Lay off points for horizontal lines making 17 equal spaces. (See Page 97, Fig. 2, for method.)

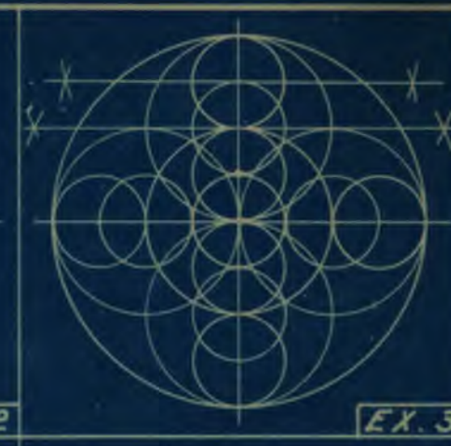
VIII. Add Title as shown on Plate 2.


13
1/4"
B
3/16"
3/16"
3/16"
6"
A
Continue Lines
C
D
A
P
EX. 1
EX. 2
C
D
B
17 Spaces
3/4"
EX. 3
EX. 4
EX. 5
EX. 6
1/2"
Title here.
PLATE

LECTURE DATE.....

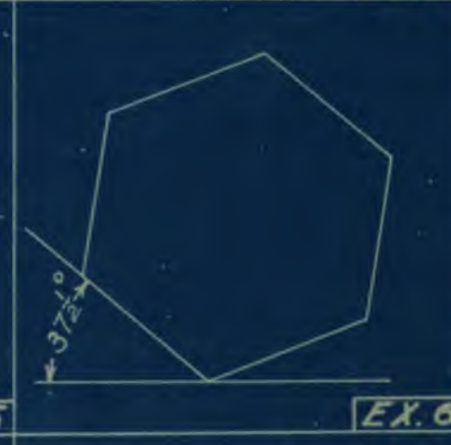

EX. 1

EX. 2


EX. 3

EX. 4

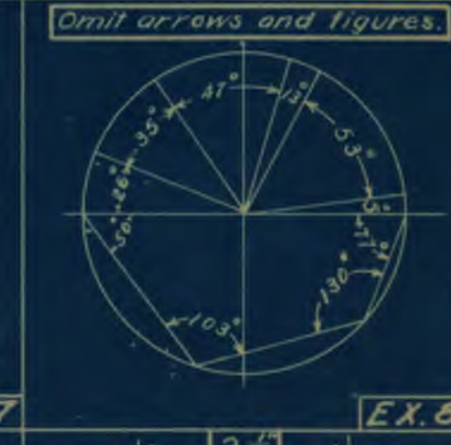

EX. 5



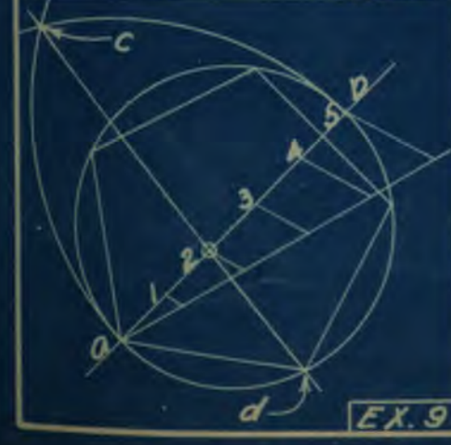
EX. 6


EX. 7

Omit arrows and figures.

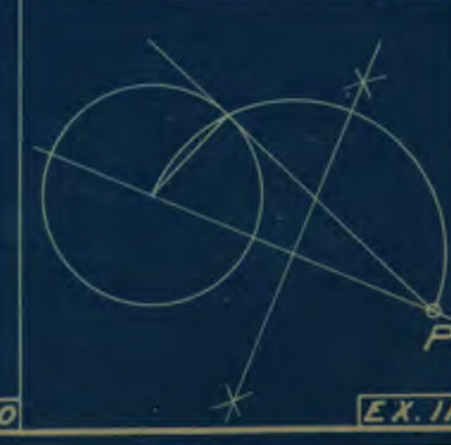


EX. 8



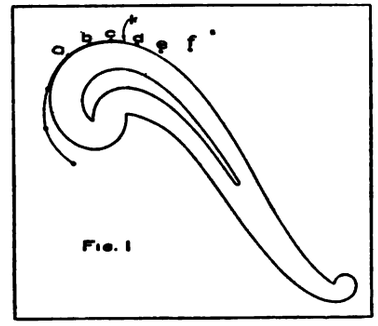
EX. 9


EX. 10



EX. 11

EX. 12



Use of French Curve or Scroll

Given a series of points to be joined by a *smooth curve.*

Find portion of Scroll to fit as many points as possible (as **a, b, c, d**). Then draw from **a** to **k** (about half way, between **c** and **d**. Change Scroll to fit **c d e f**, etc. (as many more points as possible) and continue the curve from **k** to half way between the last two points. Continue thus, always stopping the curve a little short of the last point which the Scroll seems to fit.

LECTURE DATE.....

I. From the problems on this plate a selection will be made for the drawing sheet.

II. Carry out the construction (very lightly with **6 H** pencil) for as many points as seem necessary to draw *accurately* and *smoothly* each curve. Then draw the outlines of the curve (with **2 H** pencil) using "**French Curve**" or "**Scroll.**" (See previous page.)

At ends, if French Curve does not fit the points well, short arcs may be drawn with bow pencil.

III. **Ellipse — Parabola — Hyperbola.**

These curves belong to the family of **Conic Sections**, so called because they are derived by the intersection of planes with the surface of a **Cone.**

Their exact derivation will be taken up in Page 60. This plate deals merely with certain geometrical methods of drawing them.

IV. Problem 1. **Ellipse** (First Method).

(*a*) The Ellipse can be defined as the path traced by a point, the *sum* of whose distances from two fixed points always remains constant.

The two fixed points (f_1 and f_2) are called "**Foci**" (singular, "**Focus**").
The long diameter or *Length* of Ellipse (**a b**) is called the "**Major Axis.**"
The short diameter or *Width* (**c d**) is called the "**Minor Axis.**"

(*b*) After locating the foci,* find several points in each quadrant as indicated for point **p**. Join them with the French Curve.

V. Problem 2. **Ellipse** (Second Method).

This method does not require the foci to be found.

*. It will be seen that the sum of the distances from the *Foci* to the moving point will always equal the *Major Axis*. Then, with Major and Minor Axes given, the Foci can be found by drawing arc with Radius **R** = ½ *Major Axis*, and one end of Minor Axis as centre. The rest of the construction follows the definition given above. (See diagram.)

VI. Problem 3. **Parabola** (First Method).

The Parabola can be defined as the path traced by a point moving so that its distance from a *given point* shall always be equal to its distance from a *given straight line.*

The fixed point (**f**) is called the "**Focus.**"
The straight line (**a b**) is called the "**Directrix.**"
The point (**v**) is called the "**Vertex.**"

After the focus and directrix are located, the construction is carried out as indicated for point **p**.

VII. Problem 4. **Parabola** (Second Method).

This method is useful when one desires the Parabola to have its vertex at **v** and to pass through another given point (as **a**). Neither the focus nor the directrix is needed.

VIII. Problem 5. **Hyperbola.**

The Hyperbola can be defined as the path traced by a point moving so that the *difference* of its distances from two fixed points is always constant.

The construction indicated follows the definition.
Compare with first method for the *Ellipse.*

IX. Problem 6. **Rectangular Hyberbola.**

The equation of this curve (referred to axes **O X** and **O Y**) is $x\,y = constant$. The curve is a special case of the *Hyperbola,* but further analysis of it is left to Analytic Geometry.

With one point (as **a**) located by the above equation, the curve can be drawn as indicated. If continued upward from **a** it would gradually approach **O Y** just as it approaches **O X** below.
This construction is much used in the representation of the *Theoretical Indicator Card* of a Steam Engine.

Questions for Consideration

(1) How would the Ellipse change if the *foci* were drawn nearer the centre?
(2) How would the Ellipse change if the *foci* were drawn farther from the centre?
(3) What form would the Ellipse approach in each of the above cases?

ELLIPSE

Given: $\underline{ab}$ = ①
$\underline{cd}$ = ②

(1) $R = \frac{1}{2}\underline{ab}$
(2) $\underline{f_1p} + \underline{f_2p} = \underline{ab}$
(3) Lay off $\underline{ab}$
(4) Take $\underline{r_1}$ = any length
(5) $\underline{r_2} = \underline{ab} - \underline{r_1}$

PROB. 1

ELLIPSE

Given: $\underline{ab}$ = ③
$\underline{cd}$ = ④

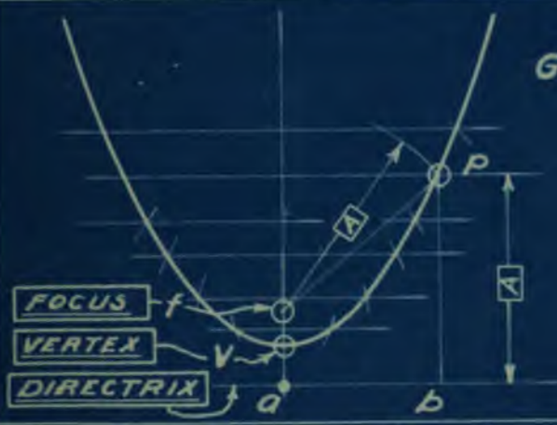
(1) $\underline{r_1} = \frac{\underline{ab}}{2}$: $\underline{r_2} = \frac{\underline{cd}}{2}$
(2) $\underline{om}$ = any line thru $\underline{o}$
(3) $\underline{mp}$ = vert : $\underline{np}$ = horiz.
(4) $\underline{p}$ = point on Ellipse

PROB. 2

PARABOLA

Given: $\underline{av} = \underline{vf}$ = ⑤

$\underline{fp} = \underline{bp}$

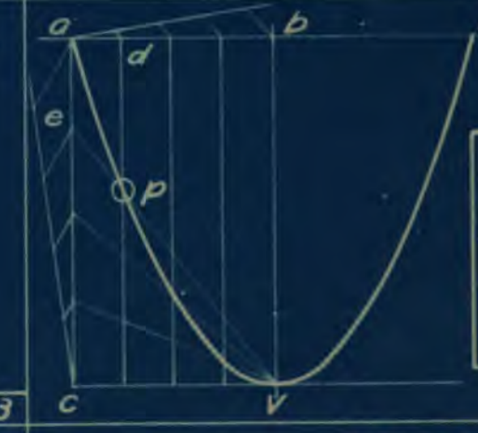


PROB. 3

PARABOLA

Given: $\underline{ab} = \underline{bk}$ = ⑥
$\underline{bv}$ = ⑦

(1) $\frac{\underline{ad}}{\underline{ab}} = \frac{\underline{ae}}{\underline{ac}}$
(2) Divide $\underline{ab}$ and $\underline{ac}$ each into $\underline{N}$ parts
(3) $\underline{dp}$ cuts $\underline{ev}$ at $\underline{p}$
(4) $\underline{p}$ = point on Parabola

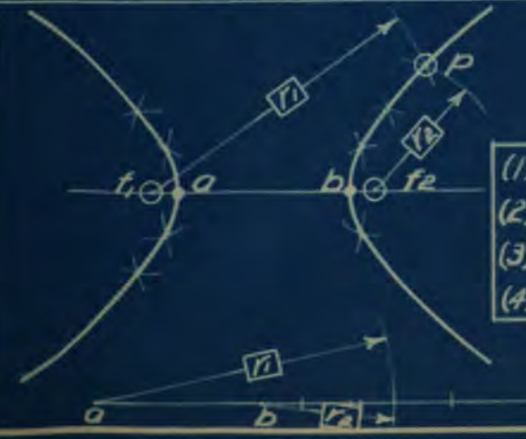


PROB. 4

HYPERBOLA

Given: $\underline{ab}$ = ⑧
$\underline{f_1a} = \underline{f_2b}$ = ⑨

(1) $\underline{f_1p} - \underline{f_2p} = \underline{ab}$
(2) Lay off $\underline{ab}$
(3) Take $\underline{r_1}$ = any length
(4) $\underline{r_2} = \underline{r_1} - \underline{ab}$

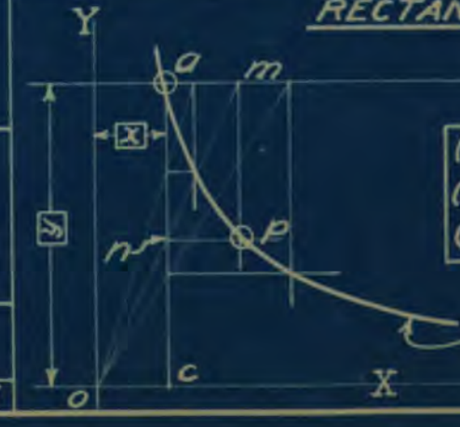


PROB. 5

RECTANGULAR HYPERBOLA

Given: $\underline{x}$ = ⑩
$\underline{y}$ = ⑪

(1) $\underline{am}$ = any line thru $\underline{o}$
(2) $\underline{mp}$ = vert : $\underline{np}$ = horiz.
(3) $\underline{p}$ = point on Curve



PROB. 6

PLATE 5

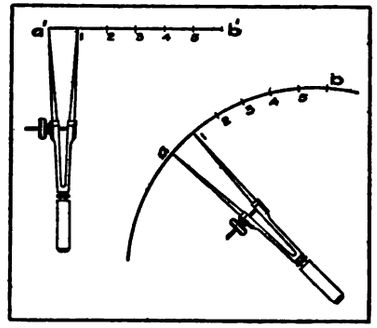


FIG. 1.

To Rectify a given Arc

Given arc **ab** (Fig. 1). Use Bow Spring Dividers. Step off *short distances* along arc **a b** and same number along straight line, **a'b'**.

This makes **a'b'** equal, approximately, arc **a b**.

Unit distance should be so short that the arc and chord are practically equal. About *one fifth* of the radius is a suitable length.

To Transfer a Gear Tooth Curve

Place *Scroll* to coincide with given curve (**m n**) (Fig. 2). Mark point **n** on scroll and draw circle **P** tangent to scroll at any convenient point (as **t**). Change scroll to new position and draw **m'n'** as shown.

Alternative Method

Omit circle **P** and use mark (as **s**) to locate curve.

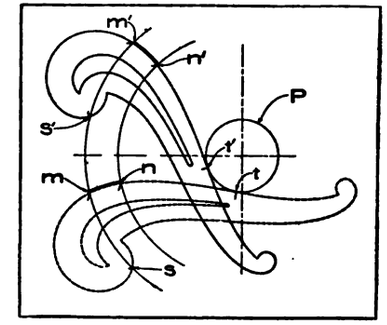


FIG. 2.

LECTURE DATE.....

PLATE 6—CYCLOIDS

I. Draw all construction lines and circles *very light.*

II. **Cycloid, Epicycloid, Hypocycloid, Involute.**

These curves belong to the family of **Cycloids.*** They may all be defined as *the path traced by a point on the circumference of a Circle which rolls on a given Line* (either Straight or Curved).

III. Problem 1. **Cycloid.**

(*a*) Rolling Circle (**R. C.**) rolls on a *Straight Line.*

(*b*) Tracing point moves from **0** to **1′**, **2′**, **3′**, etc., corresponding to successive positions of the Rolling Circle.

(*c*) Lengths of the arcs **1-1′**, **2-2′**, etc., will in each case be the distance over which the circle has rolled from its initial position at **0.**

To verify this, try a coin rolling along the edge of the T-square.
Draw a sufficient number of positions of the Rolling Circle to give smooth and accurate curve.
In stepping off distances use small dividers as shown by Fig. 1 on previous page.

IV. Problem 2. **Epicycloid, Hypocycloid, and Involute.**

(*a*) *Epicycloid* and *Hypocycloid,* Rolling Circle rolls on a *Circle*; in the first case *outside,* in the second, *inside.*

The method of constructing these curves corresponds to that used in the case of the Cycloid of Problem 1.

* Cycloid — κύκλος = "*Circle.*"
Epicycloid — ἐπι = "*upon*" + κύκλος.
Hypocycloid — ὑπό = "*under*" + κύκλος.
Involute — (Latin) **in** = "*upon*" + **volvo** = "*to roll.*"

(*b*) **Involute.**

Straight Line (circle of infinite radius) rolls on a given *Circle.* Hence a special case of the Epicycloid.

More simply — a string, held taut, is unwound from a cylinder or drum (represented by given circle). End of string describes *Involute.*
The string is taken in successive positions by drawing tangents at end of successive radii, and the proper distances out to the tracing point at end of string are stepped off in accordance with the principles explained for the previous curves. See Page 4–C–c for method of drawing tangents.

V. Problem 3. **Cycloidal Gear Teeth.**

Portions of Epi- and Hypocycloids are often used to form the contour of gear teeth. The Rolling Circles roll respectively outside and inside of a given "Pitch Circle," as shown in the diagram. The "Pitch" (arc **a b**) is the distance, measured along the Pitch Circle, between the centres of successive teeth.

On lower part of the Pitch Circle generate a short portion of each curve. Then transfer to upper part of Pitch Circle as much of these curves as is necessary to form gear teeth. Construct two teeth.
See Fig. 2 on previous page for method of transfer.

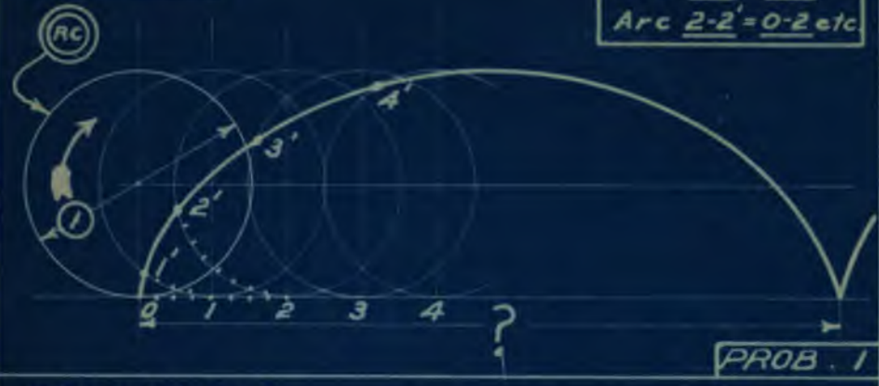
VI. Problem 4. **Involute Gear Teeth.**

Gear tooth outlines are also formed by a portion of an Involute curve. In this case the circle on which the Involute is generated is called the "Base Circle." A Pitch Circle is also required on which to lay off the Pitch of the teeth.

On the lower part of the Base Circle generate an Involute. Then transfer a portion of the curve to upper part to form two gear teeth as in Problem 3.

CYCLOID

Arc 1-1' = 0-1
Arc 2-2' = 0-2 etc



PROB. 1

EPICYCLOID

INVOLUTE

Arc 1-1' = Arc 0-1, etc.

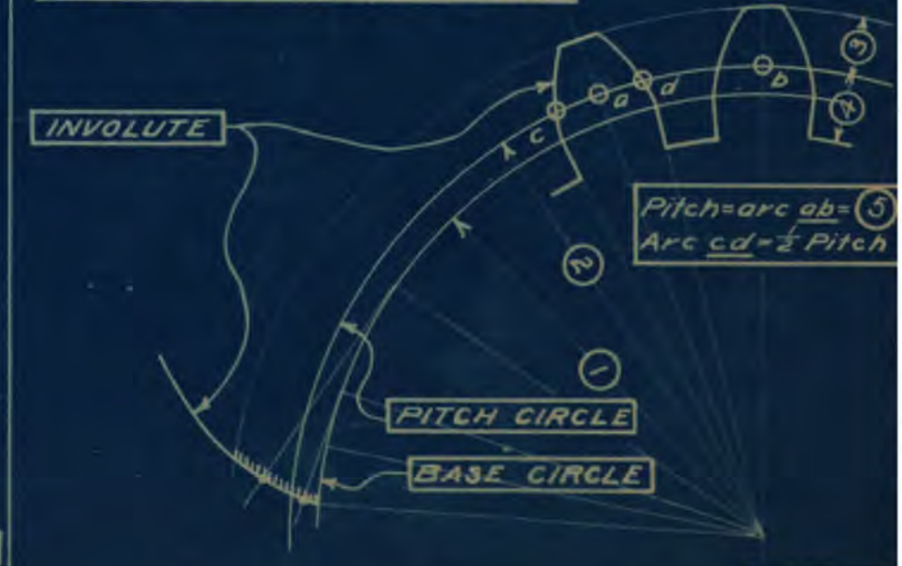
Continue Curves

PROB. 2

CYCLOIDAL GEAR TEETH

PROB. 3

INVOLUTE GEAR TEETH

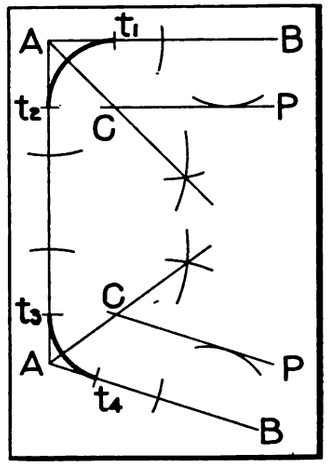


PROB. 4

PLATE 6

PLATE 7—PRACTICE IN PENCILING—STRAIGHT AND CURVED LINES, DIMENSIONING, AND CROSSHATCHING

I. Method of Drawing Tangent Arcs.



To Connect Two Straight Lines (**AA** *and* **AB**) *by Arc of Given Radius.*

(1) Bisect angle at corner **A**.

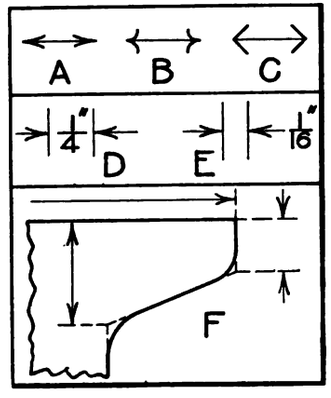
(2) Draw line **P** parallel to **AB**. (Distance from **AB** = given radius.)

(3) **C** = centre for drawing arc.

Care should be taken to stop arc exactly at tangent points, t_1, t_2, etc. It pays to draw light cross lines at these points before drawing arcs.

(4) After drawing the arcs, strengthen lines between tangent points (t_2-t_3, etc.) to same heaviness as arcs.

II. Dimensions.



(1) " *Unit marks.*" 3′ = 3 ft; 3″ = 3 in.

(2) *Arrowheads.* **A** better than **B** or **C**.

(3) *Small Dimensions.* **D** and **E** show how to avoid crowding figures.

(4) *Extension Lines* (**F**) are used to indicate where the dimension ends.

Often drawn *dotted* as in the figure, but *in this course they are to be made full.*

III. Use of Scales.

For lengths expressed in quarters, eighths, etc., use *Architect's* scale; for decimals, use *Engineer's* scale.

IV. Crosshatching.

(1) Used to indicate the " cross section " of an object.

(2) It is usually drawn with **45°** Triangle but other angles are sometimes used.

(3) Do not cover dimension figures with the hatching lines. To avoid doing so, crosshatching is drawn last.

(4) When a drawing is to be traced, the crosshatching is often omitted from the pencil sheet, or is indicated very briefly by a fringe of freehand lines around the edge of the area to be crosshatched.

V. Method of Developing Drawings.

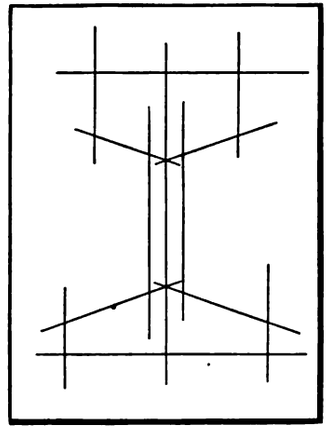
A definite process of developing Mechanical Drawings is illustrated on the following page. This will be applied to the drawing of a sheet consisting of exercises selected from Page 29.

28 PLATE 7—PRACTICE IN STRAIGHT AND CURVED LINES, DIMENSIONING, ETC.

MECHANICAL DRAWINGS, CONSISTING OF STRAIGHT AND CURVED LINES, ARE MOST CONVENIENTLY DEVELOPED BY FOLLOWING A DEFINITE SEQUENCE OF "STAGES." EACH OF THESE SUCCESSIVE STAGES IS PREFERABLY CARRIED OUT FOR THE ENTIRE SHEET BEFORE THE NEXT STAGE IS BEGUN.

ORDER OF PENCILING

Stage 1. "**Block out**" (Lightly with **6 H** pencil).

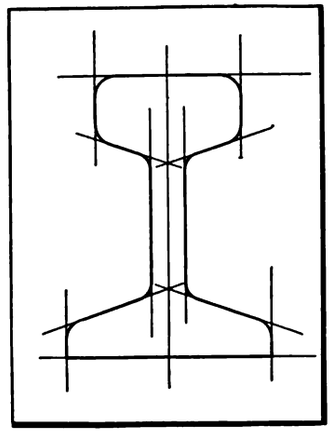


(1) Centre lines (for all symmetrical objects).

(2) General size and shape or "skeleton" of each figure.

This stage is to gauge the *arrangement* of objects on the sheet. It prevents unnecessary erasure later.

Stage 2. **Complete Outlines** (**2 H** pencil).

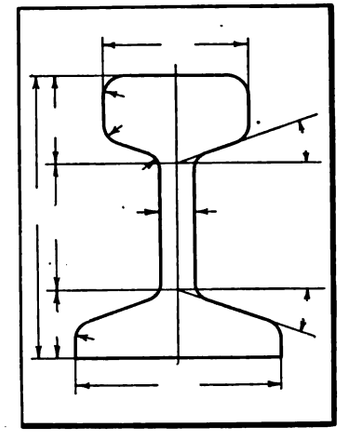


(1) Round the corners with **2 H** lead in compasses. (See Page 27-I.)

(2) Strengthen, to same heaviness, all other lines of the drawing.

Do not erase previous construction.

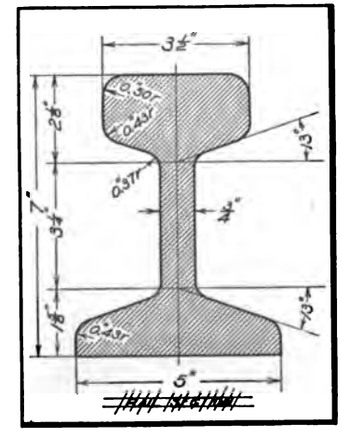
Stage 3. **Dimension Lines** (Somewhat lighter than outlines — **2 H** pencil).



(1) *Extension lines* (to indicate limit of dimension lines) — and then dimension lines. (See Page 27-II-4.)

(2) Arrow heads — free hand. (See Page 27-II-2.)

Stage 4. **Finish** (**2 H** pencil).



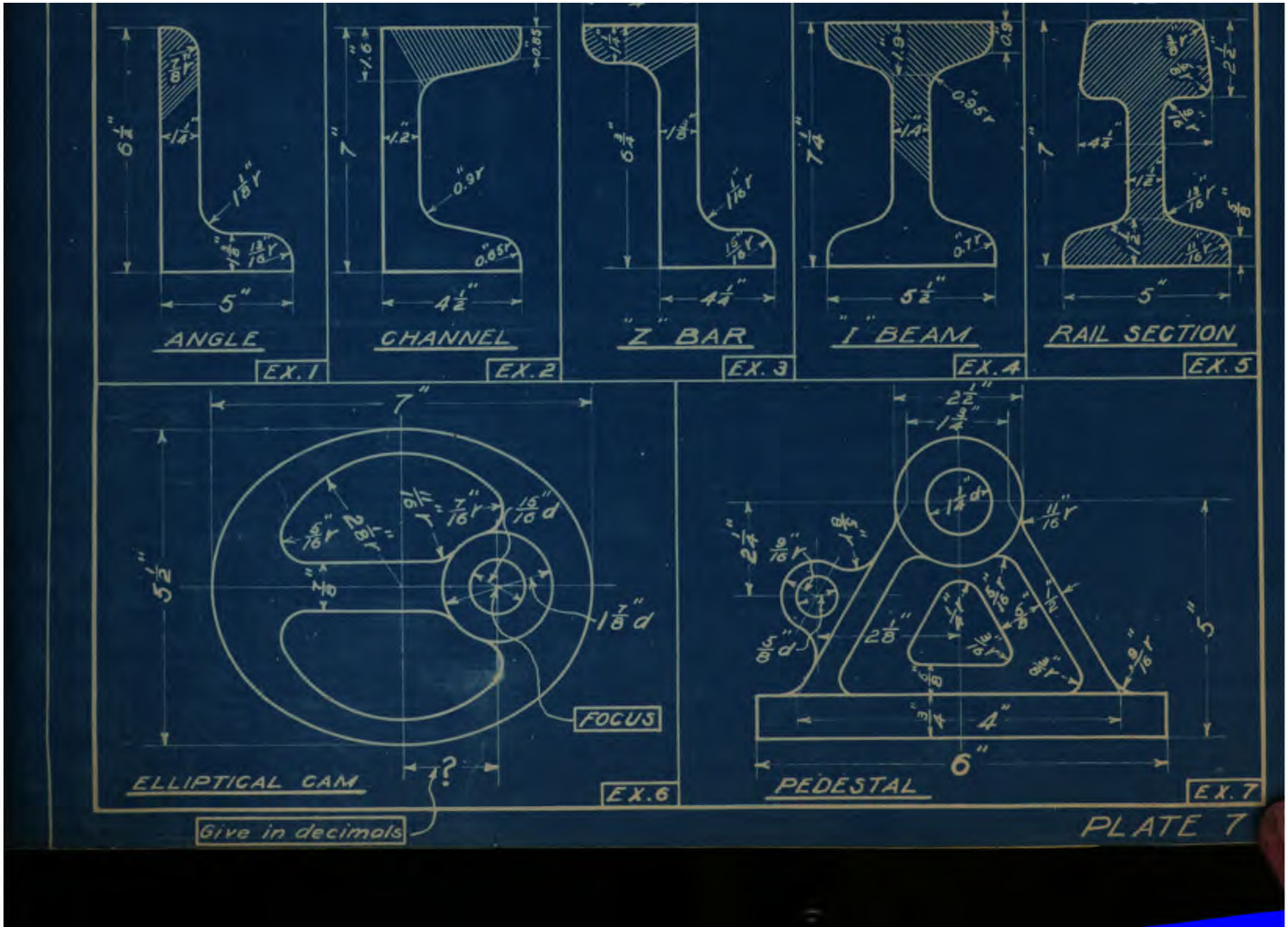
(1) Dimension Figures. (See Page 27-II-3.)

It is best at first to draw light *guide lines* as for lettering. Denominator figures rest on Base Line.

(2) Lettering.

(3) Crosshatching. (See Page 27-IV.)

The hatching lines are drawn *lightly* and spaced, *by eye alone*, about $\frac{1}{8}$ inch apart.


ANGLE
EX. 1
CHANNEL
EX. 2
"Z" BAR
EX. 3
"I" BEAM
EX. 4
RAIL SECTION
EX. 5
ELLIPTICAL CAM
FOCUS
Give in decimals
EX. 6
PEDESTAL
EX. 7
PLATE 7

I. **Instruments.**

For straight lines use " ruling pen."
For large circles use compasses (pen point).
For small circles use " bow pen."
Have *both nibs* touch the paper.
Do not fill pen too full.
Clean pen often with pen-wiper.

II. **Types of lines.**

(1) Full.
(2) Dotted.
(3) Dot and Dash. (See Page 101-IV-1.)

III. **Tracing Cloth.**

Tracing cloth will be seen to have a *dull* and a *glazed* surface.
Ink on the *dull* side.
Prepare the cloth by rubbing with powdered chalk (" pounce "). Care should be taken to brush off all the powder before applying ink.

IV. **Method of Inking Drawings.**

Various sheets previously drawn in pencil will be given back for inking exercises, either on the same sheet or on tracing cloth.
On the following page will be found an illustration of method to be used.

V. **Checking.**

After a drawing sheet is completed it is customary in practice to adopt the process of " checking " to discover any mistakes or omissions in the information conveyed by it. Procedure as follows:

(*a*) Apply *four tests* to every dimension.
1. Have the *dimension figures* been correctly copied from the original drawing or notes?
2. Have they been laid out " to scale "? (Measure the drawing and compare with dimension figures.)
3. Are " *unit marks* " shown? (See Page 27-II-1.)
4. Are *arrow heads* and *"extension lines"* shown? (See Page 27-II-4.)

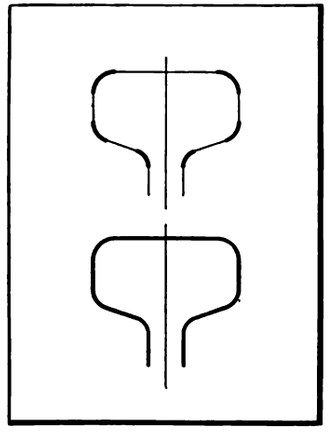
(*b*) All statements and specifications should also be verified.

(*c*) Place small check mark (with red pencil) neatly over each item found correct.
If error or omission is found, indicate in pencil the desired correction.

INKING IS SIMPLIFIED BY COMPLETING ONE PROCESS AT A TIME SO AS TO AVOID CHANGING INSTRUMENTS OR INK. EACH ONE OF THE SUCCESSIVE STAGES ILLUSTRATED BELOW IS, THEREFORE, PREFERABLY CARRIED OUT FOR THE ENTIRE SHEET BEFORE THE NEXT IS BEGUN.

ORDER OF INKING

Stage 1. Outlines (Black Ink).

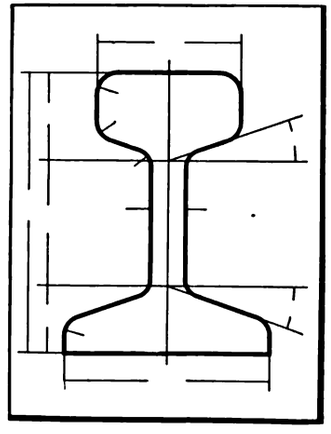


(1) *Curves* before *straight lines.*

This gives best results in joining curves and straight lines, and in rounding corners.

(2) On tracings outlines should be heavy enough to make a clear blue print.

Stage 2. Dimension Lines (Red Ink).

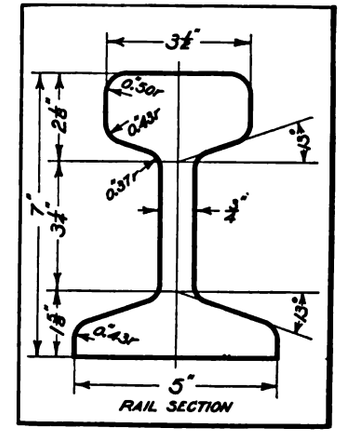


(1) Dimension and Extension Lines.

(2) Centre Lines (if any).

Use *fine* lines in contrast to heavier outlines of objects.

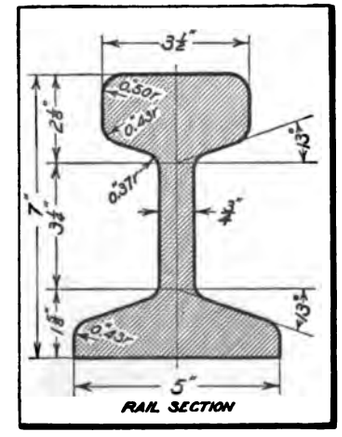
Stage 3. Arrow Heads, Figures, and **Lettering** (Black Ink).



(1) Drawn *freehand* with ordinary writing pen.

(2) To preserve straight alignment of lettering, draw light pencil guide lines on tracing cloth.

Stage 4. Crosshatching (Black Ink).



Use fine lines.

Do not cover any dimensions with hatching lines.

LECTURE DATE.....

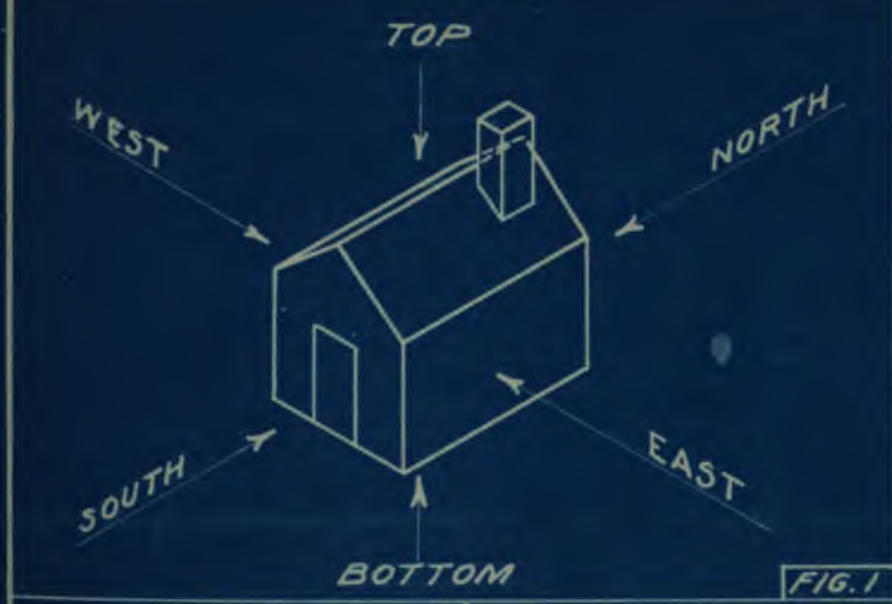


FIG. 1

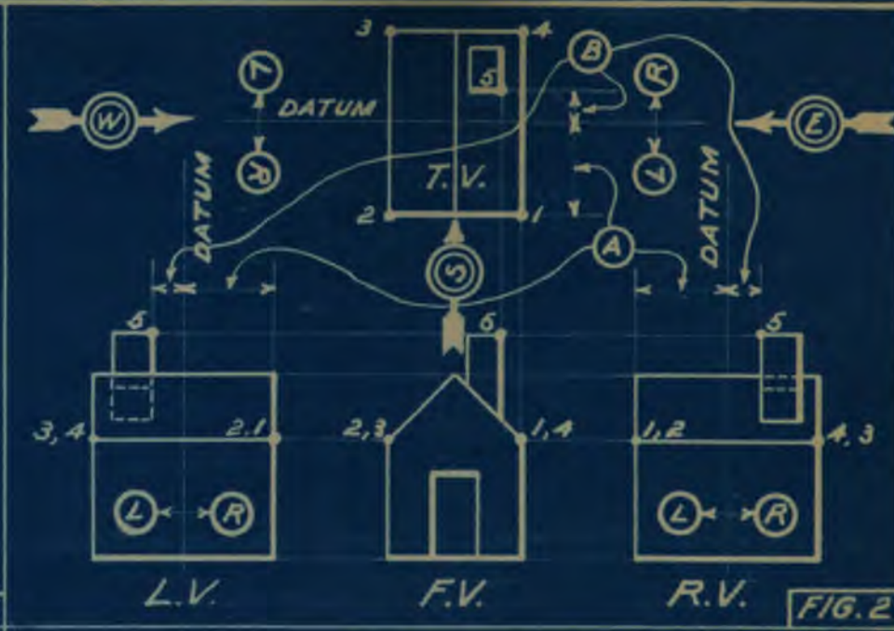


FIG. 2

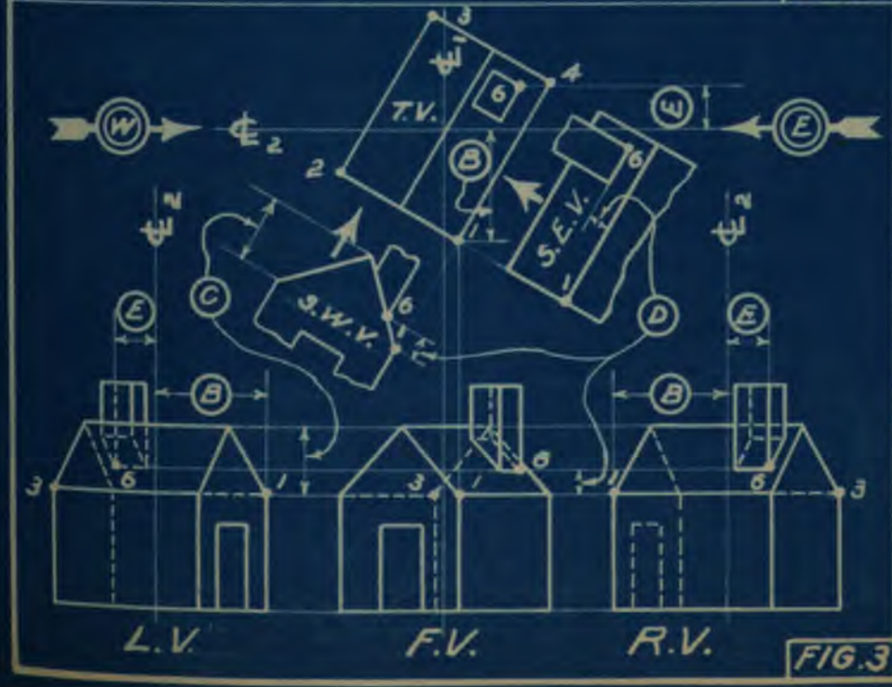


FIG. 3

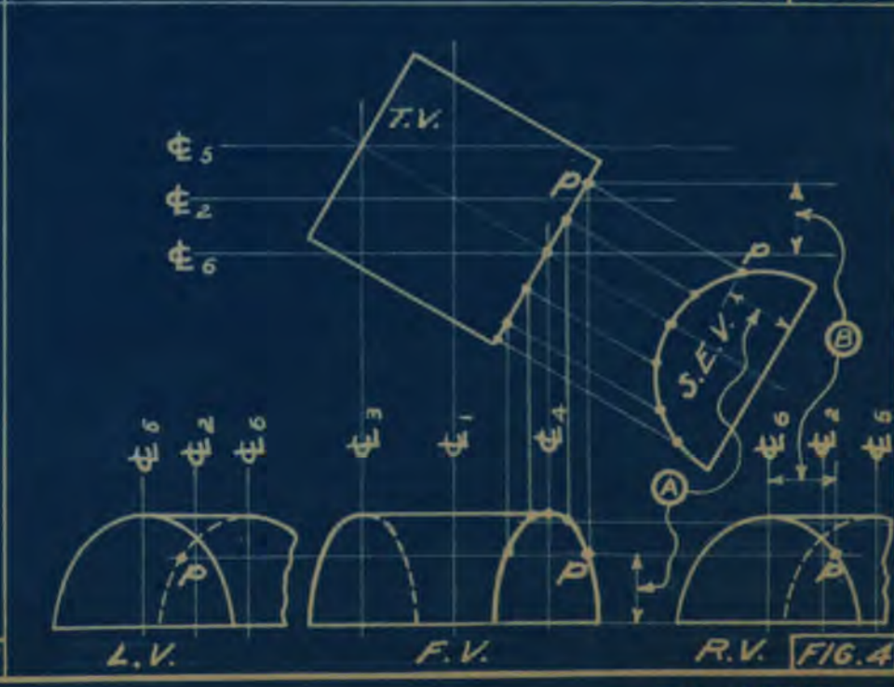


FIG. 4

PLATE 8

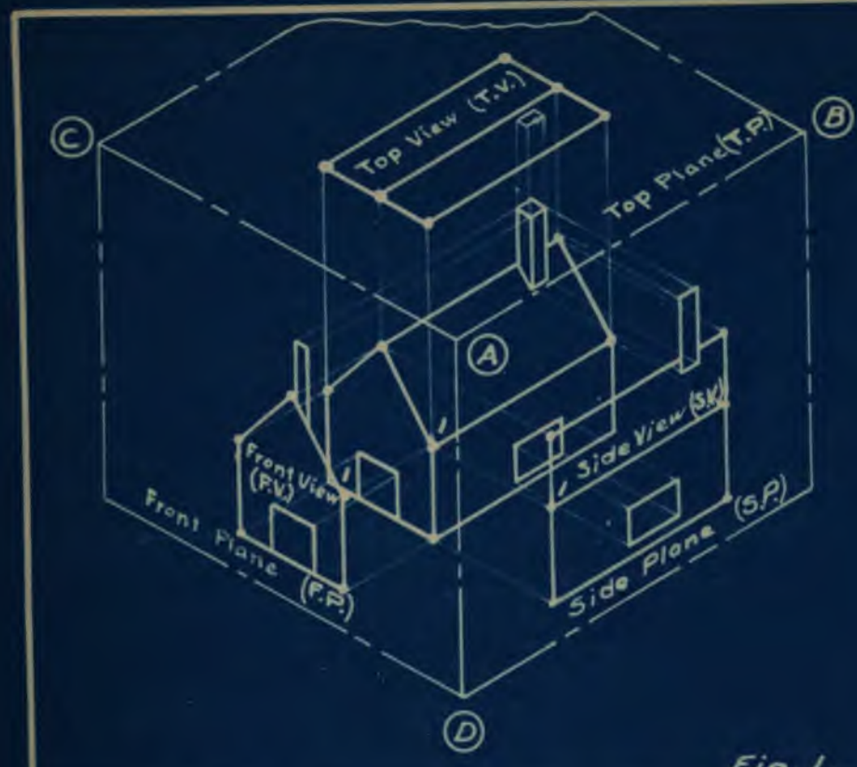


Fig. 1.

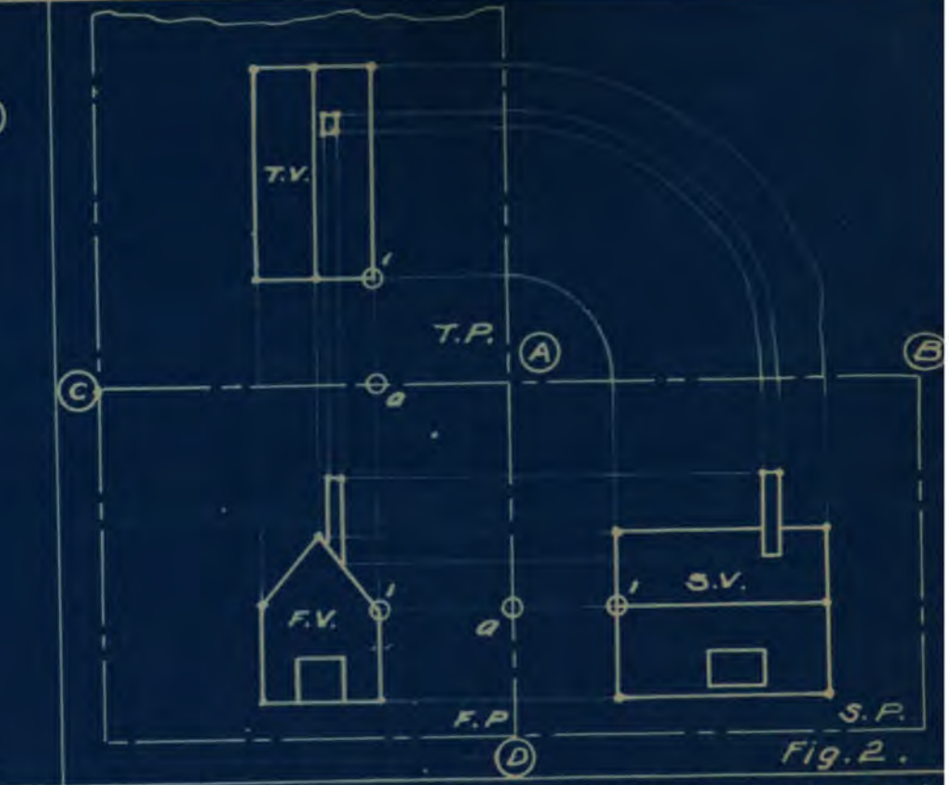


Fig. 2.

1. Consider object surrounded by Three Planes, F.P., S.P., and T.P. as shown in Fig. 1. These are called "PLANES OF PROJECTION."
2. Let rays perpendicular to each plane pass from every point of object to these planes.
3. The intersection of rays and their respective planes will trace 3 Views F.V., S.V. & T.V. (Fig 1.)
4. These views are called PROJECTIONS of the object:
(a) More accurately, ORTHOGRAPHIC PROJECTIONS because rays make Right Angles with their respective planes [ὀρθός = Right & γράφειν = to Draw].
(b) By additional planes a Bottom View, a Left Side View and a Rear View can be obtained.

5. Consider Planes of Projection to be separated along AB. Turn T.P. on AC and S.P. on AD and spread all three planes out flat. Resulting location of views will be as in Fig. 2.
6. Note: (a) T.V. is above F.V. and S.V. at side of F.V.[2]
(b) Point 1 in T.V. is Vertically over point 1 in F.V.
(c) Point 1 is on some Horizontal Line in S.V. and F.V.
(d) Distance a,1 in S.V. = distance a,1 in T.V.
These 4 relations are true for all pts in the 3 Views.
7. Above principles apply to representation of all objects by the method of Orthographic Projection.

[2] NOTE: F.V. often called FRONT ELEVATION.
S.V. " " SIDE ELEVATION
T.V. " " PLAN

ORTHOGRAPHIC PROJECTION PLATE

LECTURE DATE.....

I. From the problems here given, a selection will be made for several drawing sheets.

Study carefully Pages 34 and 35. Apply principles there explained to the development of the problems given on Plate 10.

II. Adapt the **Order of Penciling** as given on Page 28 to these sheets thus:—

Stage 1. (*a*) Lay out Datum * Lines to locate positions of Views.

(*b*) Block out all Views of the objects lightly.

As far as possible, develop all views of an object together instead of completing one view before beginning another. For instance: Where a horizontal line is to appear in **F.V.** and **R.V.** or **L.V.** draw it, at one stroke, through both views. Similarly for vertical lines in **F.V.** and **T.V.**

This will be found to economize time and to assist in understanding the relation of the various views.

When blocking out, draw hidden lines light and full: a light "*d*" placed on them will indicate that they are to be dotted later. (Stage 2.)

Stage 2. Strengthen *outlines*, drawing visible lines *full*, and hidden lines *dotted*.

Stage 3. *Numerical dimensions* are to be omitted on these sheets.

Stage 4. *Lettering*, etc.

III. Ink in:—

(*a*) Datum Lines (*Red-light*).

(*b*) Border line (*Black-heavy*).

* As suggested in footnote on Page 34, *Centre Lines* in any symmetrical views of an object are usually selected as *Datum Lines*. The Centre Lines of subordinate parts (if symmetrical) may also be used as secondary Datum Lines and are usually drawn. (See Centre Lines of Chimney and Ell of the house in *Problem 1*.)

IV. PROBLEMS

Prob. 1. Given **F.V.**, **T.V.**, and **R.V.** of house, draw **L.V.**

Prob. 2. Given **F.V.**, **T.V.**, and **R.V.** of object, draw **L.V.**

Prob. 3. Given **F.V.**, **T.V.**, and **L.V.**, draw **R.V.**

Prob. 4.† Suppose the object of Problem 3 be turned on its base through a given angle θ. Draw the **T.V.**, **F.V.**, **R.V.**, and **L.V.** of the object in this position.

Prob. 5. Given **F.V.**, **T.V.**, and **L.V.**, draw **R.V.**

Prob. 6.† Object of Problem 5 turned on its base through given angle Φ. Draw **T.V.**, **F.V.**, **R.V.**, and **L.V.**

Questions for Consideration

(1) **T. V.** of an object is represented by a circle inside of a square. What different *front views* are consistent with this **T. V.**?

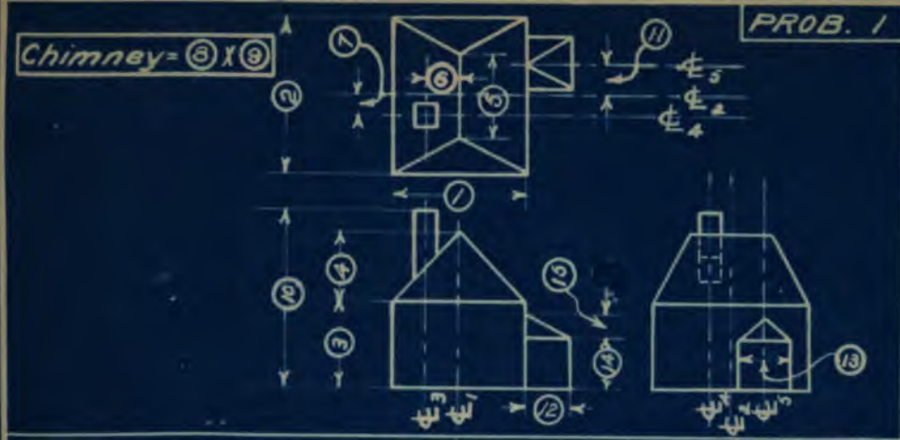
(2) **F. V.** of an object consists of three concentric circles. What *side views* can be drawn?

(3) With the inmost circle *dotted*, what *side views* can be drawn?

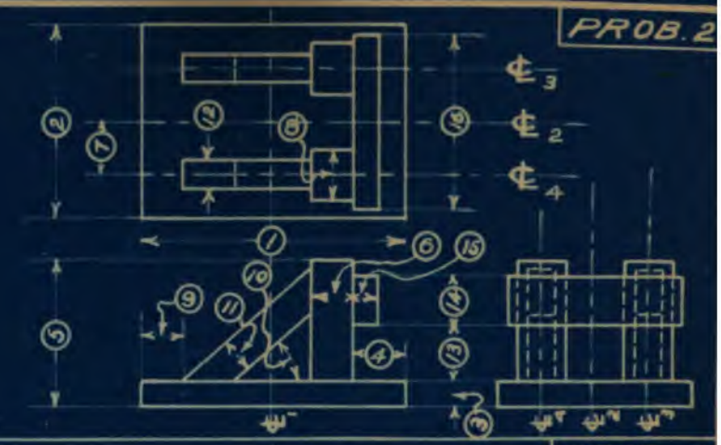
(4) Can any view of a curve be a straight line?

† In Problems 4 and 6 a view corresponding to **S. E.V.** of Fig. 4, Page 35 will be found necessary.

PROB. 1



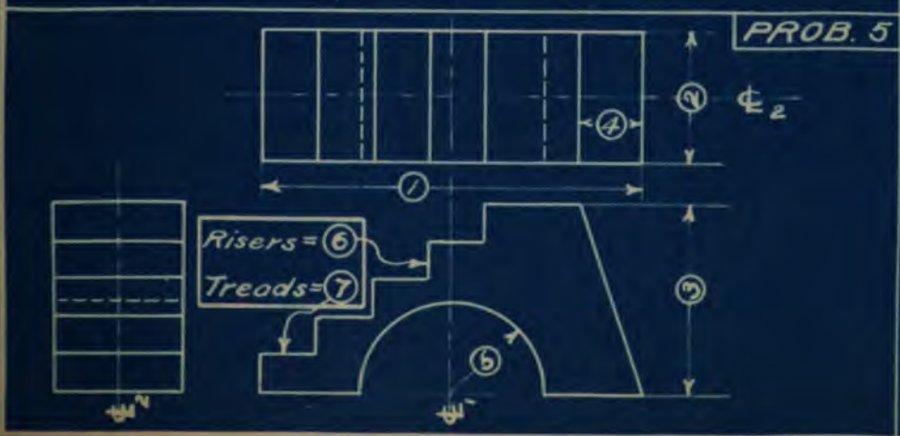
PROB. 2



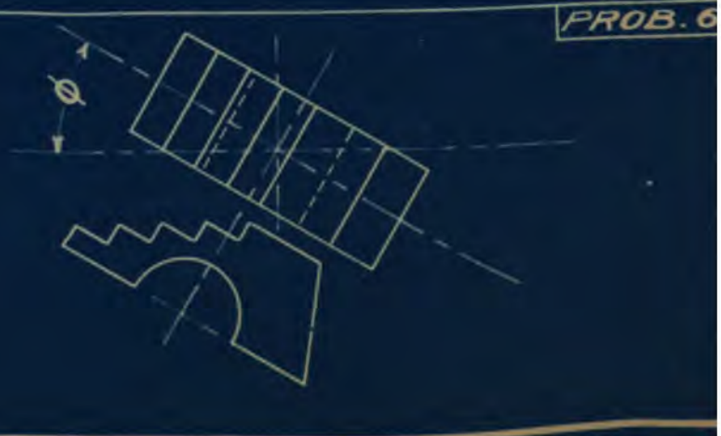
PROB. 3

PROB. 4

PROB. 5



PROB. 6



PLATE

PLATE 11

ORTHOGRAPHIC PROJECTION—TRUE SIZES AND TRUE LENGTHS

LECTURE DATE. . .....

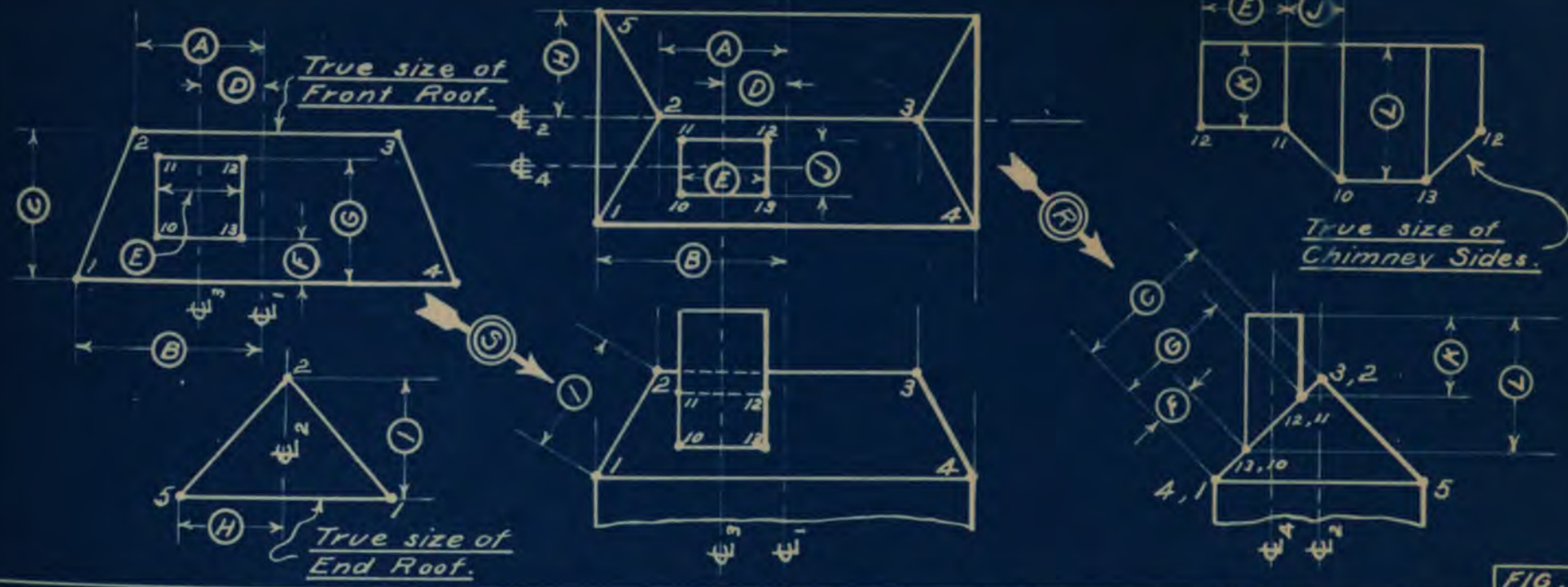


FIG. 1

Chimney = (8)

Draw True Sizes of Roof Planes A & B, & Chimney Sides.

Complete the Views.

PROB. 1

Chimney = (9)

Draw True Sizes of Roof Planes A, B, C, & Chimney Sides.

Complete Views.

PROB. 2

PLATE 11

PLATE 12

INTERSECTION OF PRISM BY PLANE—DEVELOPMENT

LECTURE DATE..... .....

PLATE 12

INTERSECTION OF PRISM BY PLANE—DEVELOPMENT

FROM NOW ON, ALL THE PROBLEMS OF THE COURSE ARE BASED ON THE PRINCIPLES OF ORTHOGRAPHIC PROJECTION. THIS TERM WILL, THEREFORE, BE OMITTED FROM THE HEADINGS AND ONLY THE TITLE OF THE SPECIAL PROBLEM WILL BE GIVEN

I. Given a Square Prism cut by two planes **P** and **Q** as shown in Fig. 1. To find:

(*a*) The true size and shape of the resulting *Intersections.*

(*b*) The shape and size of a sheet of material which when folded will produce that portion of the surface of the prism which is below the *Cutting Planes* **P** and **Q**. The name given to this process is "*Development of the Surface.*"

II. (*a*) Draw **F. V.**, **T. V.**, **R. V.** of the prism as it appears before it is cut off.

(*b*) Across **F. V.** draw lines **P** and **Q** representing the edges of the given *Cutting Planes* and find **T. V.** and **R. V.** of the resulting *Intersections.*

The Cutting Plane **Q** intersects* the edge **2** at point **11** in **F.V.** Identify **11** on same edge **2** in **R.V.**

Point **10** (**R.V.**) can be located by distance **A** taken from **T.V.**

By joining points 9–10–11–12–13–14 the *Intersections* are completed in **R.V.**

(*c*) Obtain *True Size* of Intersections by the principles of the previous plate. (Pages 44 and 45.)

Note the convenient location of the True Sizes.

* The point where an edge is cut off must first be found in a view where the Cutting Plane is seen "edgewise" and appears as a straight line.

(*d*) The *Development* is built up point by point, taking required distances from those views where they appear in their *true length.*

Points **9**, **11**, **12**, and **13** are identified on their respective edges and located by their heights from the base. (See Distance **E**.)

To locate point **10**, it is convenient to use a "*Surface Line*" (**S. L.**) passing through the point. This line can be located on the Development (see Distance **C**), and point **10** identified on it (see Distance **D**).

S.L. = "Surface Line."

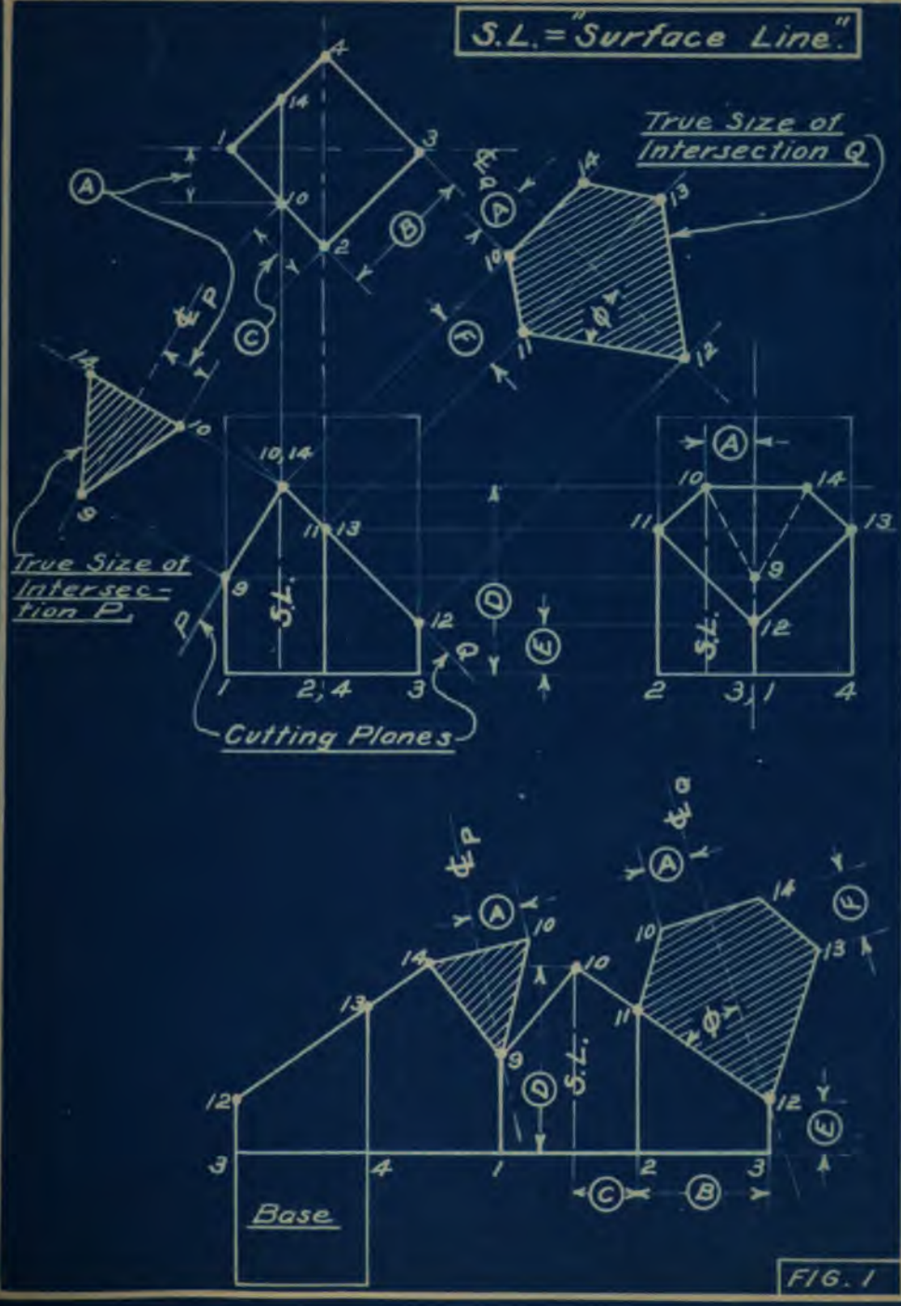
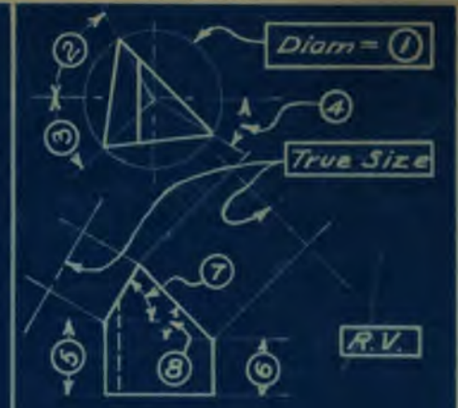


FIG. 1



Development

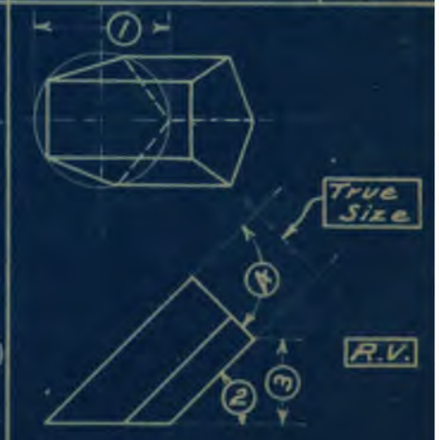
PROB. 1

Development

PROB. 2

Development

PROB. 3



Development

PROB. 4

LECTURE DATE.....

I. Given a triangular Pyramid cut by two slanting planes. (See **P** and **Q** in Fig. 1.)

To find: (*a*) True Size of Intersections.

(*b*) Development of the surface of the Pyramid below the Cutting Planes.

II. General method same as for Prism of previous plate.

(*a*) Draw the three views of the Pyramid as it appears before it is cut off.

(*b*) Draw Cutting Planes in **F.V.** and find resulting Top and Side Views of the Intersections.
Points **5**, **6**, and **9** (on edges of Pyramid) are found in **F.V.** and then identified *on same edges* in **R.V.** and **T.V.**
Point **7** (in slanting side of Pyramid) is located by passing through it a "*Surface Line*" (**S.L.** in **F.V.**).

This Surface Line can be located in **T.V.** (by points **1** and **10**) and in **R.V.** (by distance **A**), Point **7** can then be identified on it in both views.

(*c*) Obtain True Size of Intersections as in the case of Prism of previous plate.

(*d*) Draw Development.
As in the two previous plates, this is built up by laying off true lengths from *point* to *point*.
The true length of edge **1-4** = distance **C** (in *Front View*).
The true length of base line **4-2** = distance **D** (in *Top View*).
The true length of edge **1-2** cannot be found directly in any of the three views but a method for finding it is indicated in Fig. 3 To make this clear refer to Fig. 2.

Imagine a "plumb line" dropped from vertex **1** to **X** and from **X** a line drawn in base out to **2**. Angle at **X** = 90°. This gives two sides of a *right triangle*, **1–X–2**, the hypotenuse of which is the required true length of the edge **1–2**.
True length of **1–X** is obtained from **F.V.** (= altitude **E** of Pyramid).
True length of **X–2** is obtained from **T.V.** (= distance **F**).
These two lengths are combined in Fig. 3 to give the right triangle.
Distance **G** = required true length of edge **1–2**.
True length of any portion of this line, as **2–5**, can be found by similar method.

To locate point **7** use again the device of inserting the Surface Line (**S. L.**) and then apply the same method as for the edge **1-2** above. Compare Figs. 2 and 4.*
The remainder of the Development can be worked out by using the proper right triangle for any true length not given directly in one of the three views.

III. The above processes in finding true lengths of lines may be formulated thus:—

(1) *Vertical* lines are seen in their true length in *Front* and *Side* Views.

(2) *Horizontal* lines are seen in their true length in *Top* View.

(3) The true length of any other line can be found when the positions of its two end points are known. The *difference in height* of the two points (taken from Front View or any Elevation) and the *distance between the Top Views* of the points make two legs of a right triangle, the hypotenuse of which is the desired true length.

* It is best to arrange the true length construction on the same level with the Front View, so that all heights can be brought over from it with the T-square.

S.L. = "Surface Line"

FIG. 1

FIG. 2

FIG. 3

FIG. 1

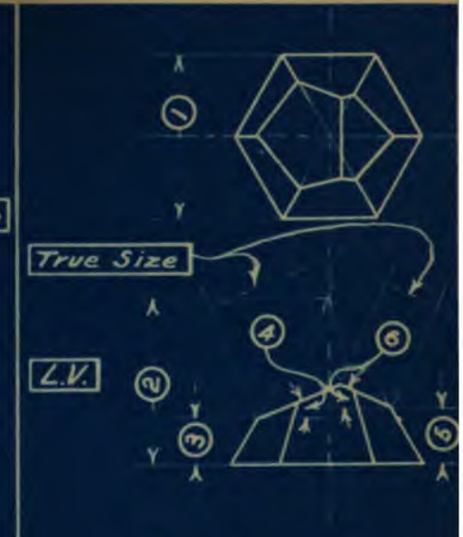
FIG. 4

FIG. 5

Development

Development

PROB. 1



Development

PROB. 2

Development

PROB. 3

Development

PROB. 4

PLATE 13

PLATE 14

INTERSECTION OF CYLINDER AND CONE BY PLANE—DEVELOPMENT

LECTURE DATE.....

PLATE 14

INTERSECTION OF CYLINDER AND CONE BY PLANE—DEVELOPMENT

I. Given a **Cylinder** cut by a slanting Plane. (Fig. 1.) Find:—

(*a*) *True Size* of Intersection.

(*b*) *Development* of the Surface of the Cylinder.

II. (*a*) In order to carry out a construction on any curved surface, we must first locate certain "**surface lines**" (lines known to lie in the surface) in such a way that they can readily be identified in all views, and then *upon these surface lines* work out the required construction, the method being similar to that of the previous plate.

In the case of a Cylinder, the *surface lines* which can be most readily identified in the various views are those which are parallel to the axis of the cylinder, as lines **a, b, c, d,*** etc., in Fig. 1.

(*b*) After the *surface lines* have been drawn in **F. V.** and in **R. V.** the problem becomes simply to find at what point in **F. V.** each *surface line* is cut off by the Cutting Plane, and then to identify this point (*on same surface line*) in **R. V.** (For instance, point **2** on Surface Line **d.**)

By joining points (found in this way) on consecutive surface lines we can draw the required Intersection.

Select as many Surface Lines as are found necessary to draw *accurately* and *smoothly* the curve of intersection. They can be lettered for convenience of identification during construction. (See **a, b, c,** etc., in Fig. 1.)

(*c*) The True Size of the Intersection is derived from the other views as in the case of the Prism of Plate 12.

(*d*) Starting from any Surface Line as a Datum, the Development can be built up by transferring true lengths of lines, as in the case of the Prism† of Plate 12.

III. Intersection of **Cone** by Plane. (Fig. 2.)

(*a*) General method is similar to that of the Cylinder, the chosen surface lines in this case, however, being those from the vertex **V** to points in the base. (See lines **a, b, c, d,*** etc.)

The Cone should be drawn first as it appears before it is cut off by plane.

(*b*) The Development can be built up (from any Surface Line as a Datum) by finding the true lengths of (1) the base arcs between successive Surface Lines and of (2) the Surface Lines themselves. Method similar to that of the Pyramid† of Plate 13.

The *true length* of Surface Line **a** is evidently the distance **B** in **F.V.** The true length of **2–5**, then, will be **C**; of **3–6** will be **D**, etc.

* Such *straight* Surface Lines are often called **Elements.**

† The Cylinder may be regarded as a Prism (and the Cone a Pyramid) of an infinite number of sides. In both cases the edges become the Surface Lines or Elements and the plane surfaces between the edges become the smooth curved surface of the Cylinder or Cone.

CONIC SECTIONS

LECTURE DATE.....

PLATE 15—INTERSECTION OF CONE BY PLANE—SECOND METHOD

CONIC SECTIONS

I. If the base of a Cone is a circle and its axis is perpendicular to the base, an alternative method to that used in the previous plate may be employed by selecting "Surface Lines" *parallel to the base.*

These Surface Lines appear as circles in Top View and as straight horizontal lines in Front and Side Views. (See line **b** in Fig. 1.)

As in the previous method, the points where a given Cutting Plane intersects the selected Surface Lines can be located in **F. V.** and then identified in **T. V.** and **R. V.**

Joining the consecutive points thus found will produce the required curve of intersection.

II. Planes cutting the surface of a right circular Cone (base a circle, axis perpendicular to base) produce different curves of intersection, depending upon the inclination of the planes.

These curves are called "Conic Sections," thus:—

(*a*) Plane perpendicular to axis — **Circle.**

(*b*) Plane crossing Cone — **Ellipse.**

(*c*) Plane parallel to slanting Element — **Parabola.**

(*d*) Plane parallel to axis of Cone — **Hyperbola.**

In the case of the *Hyperbola* we get *two curves*, the second one inverted, if we consider the plane to cut the Cone produced above the vertex.

Further consideration of *Conic Sections* is left for Analytic Geometry.

III. PROBLEMS

Prob. 1. Cone cut by a plane which is parallel to its axis. Draw *Front View* and *True Size* of Intersection.

The method follows the principles indicated above.

Note the convenient position for True Size of Intersection in relation to the Cutting Plane.

Prob. 2. Right circular Cone cut by planes as indicated. Draw *Top View* and *True Size* of corresponding "Conic Sections." (See II on this page.)

Prob. 3. A bell-shaped surface (or "curved cone") is cut by given planes **A** and **B.**

Draw *Top View* and *True Size* of Intersections. Show Top View complete.

The solution of this problem is similar to that of the Cone with straight line contour. The use of Surface Lines is shown for one or two points.

Any surface the "cross section" of which is a *circle* can be treated in same manner when intersection by a plane is required.

IV. Question for Consideration.

If a Development of a Cone were also required, could the above type of Surface Line (i.e., circles parallel to base) be used? If so, how?

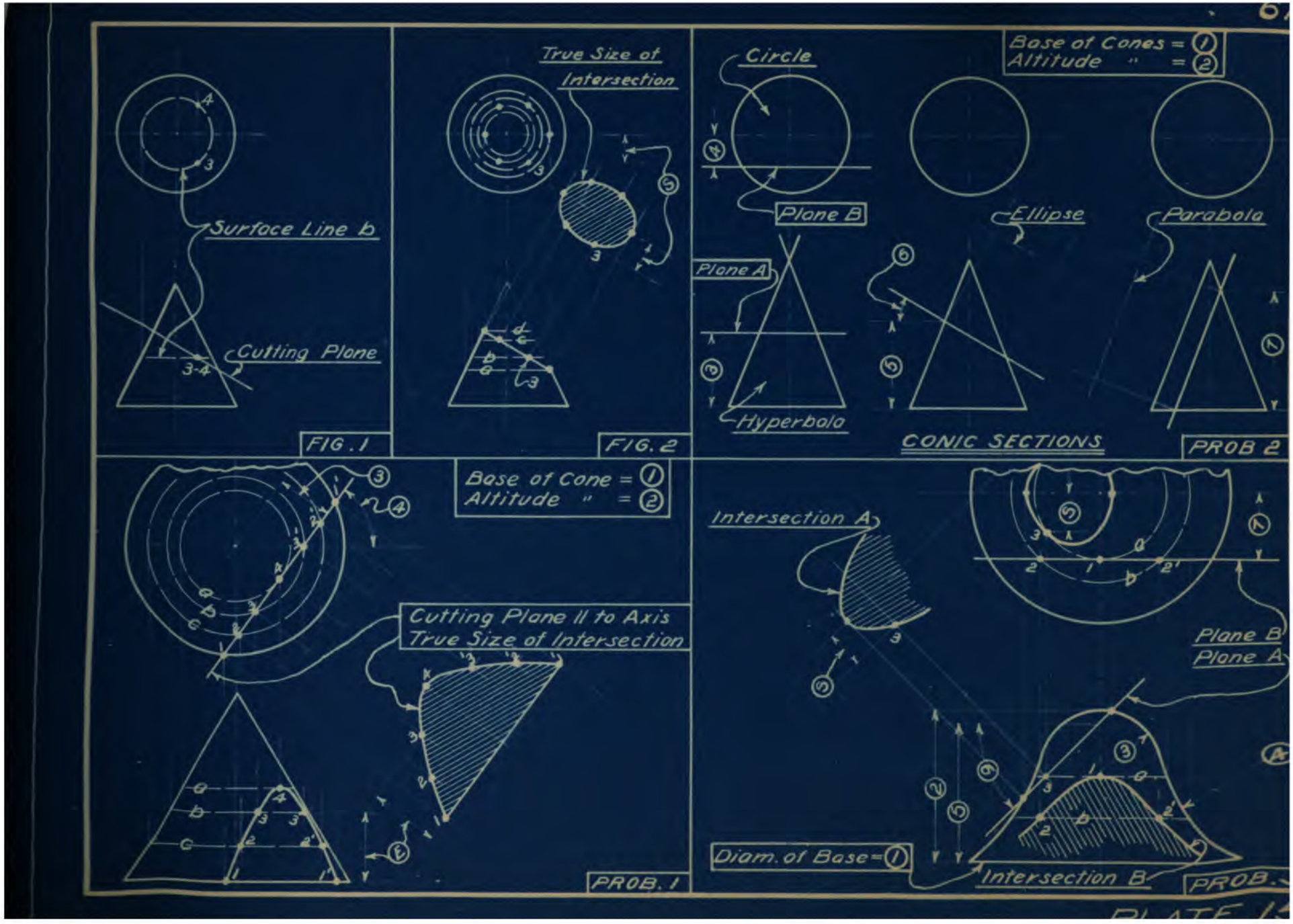

Surface Line b
Cutting Plane
3-4
FIG. 1
True Size of Intersection
FIG. 2
Circle
Base of Cones = 1
Altitude " = 2
Plane B
Ellipse
Parabola
Plane A
Hyperbola
CONIC SECTIONS
PROB 2
Base of Cone = 1
Altitude " = 2
Cutting Plane ll to Axis
True Size of Intersection
PROB. 1
Intersection A
Plane B
Plane A
Diam. of Base = 1
Intersection B
PROB.

PLATE 16

INTERSECTION OF SURFACES—NUT FOR BOLT

LECTURE DATE.....

PLATE 16

INTERSECTION OF SURFACES—NUT FOR BOLT

I. Method of construction in all the problems of this plate follows the principles of the previous plates.

II. In each problem:—

(1) *Draw Complete Top Views.*

See Page 17, Ex. 5, for method of constructing hexagon.

(2) In *Side Views* draw "half section" as indicated in Problem 1.

III. Problem 1. Intersection of *Cone* and *Hexagonal Prism.*

(*a*) The curve seen in true size on the front face of the prism is evidently a portion of an Hyperbola.
The same curve appears on the slanting faces, in both front and side views, but in both cases more or less foreshortened.

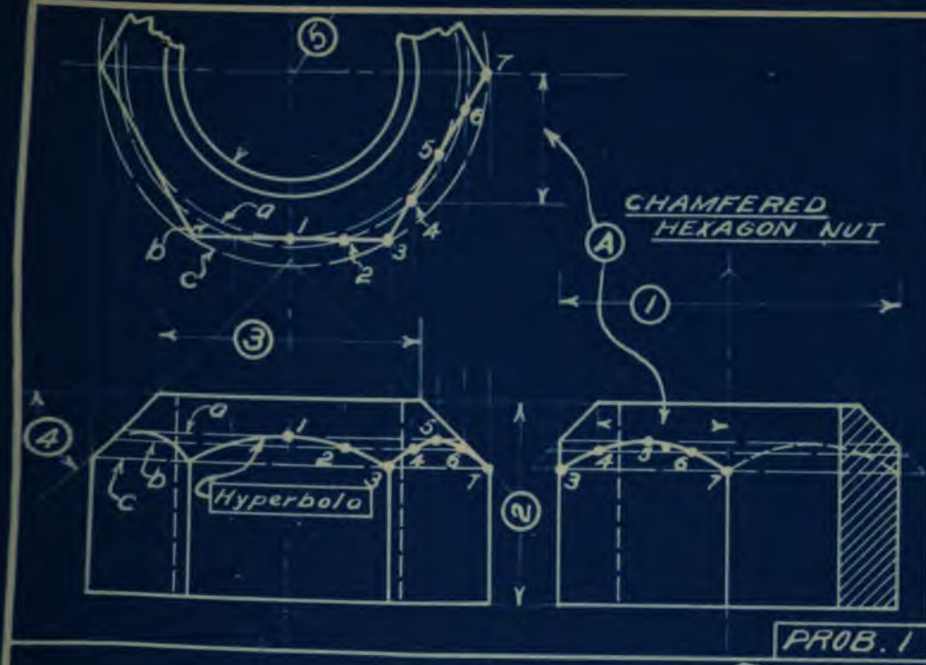
(*b*) Nuts thus cut off by a cone are said to be "**chamfered.**"

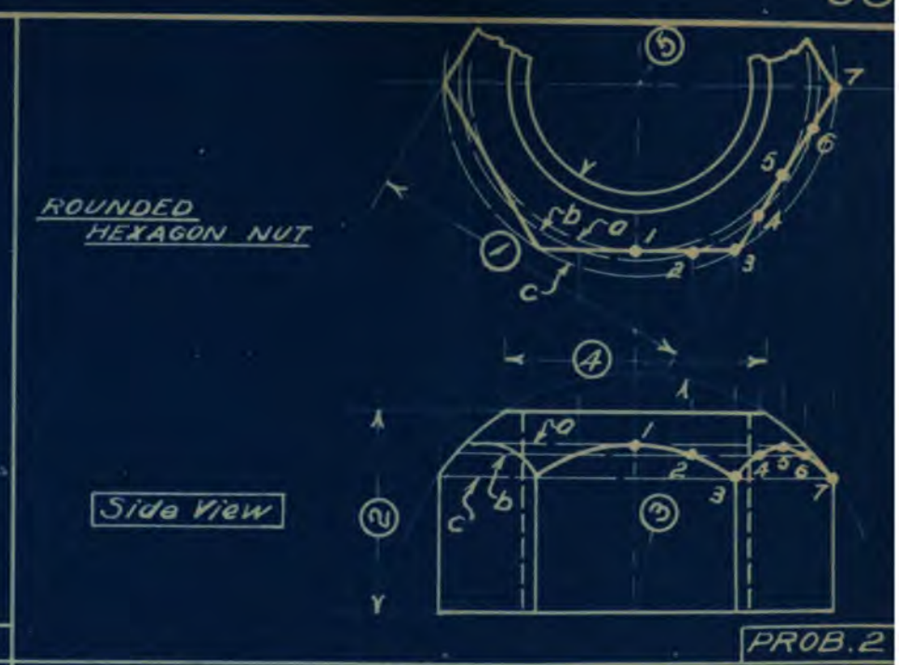
(*c*) Front View shows the nut "across *corners.*"
Side View shows the nut "across *flats.*"

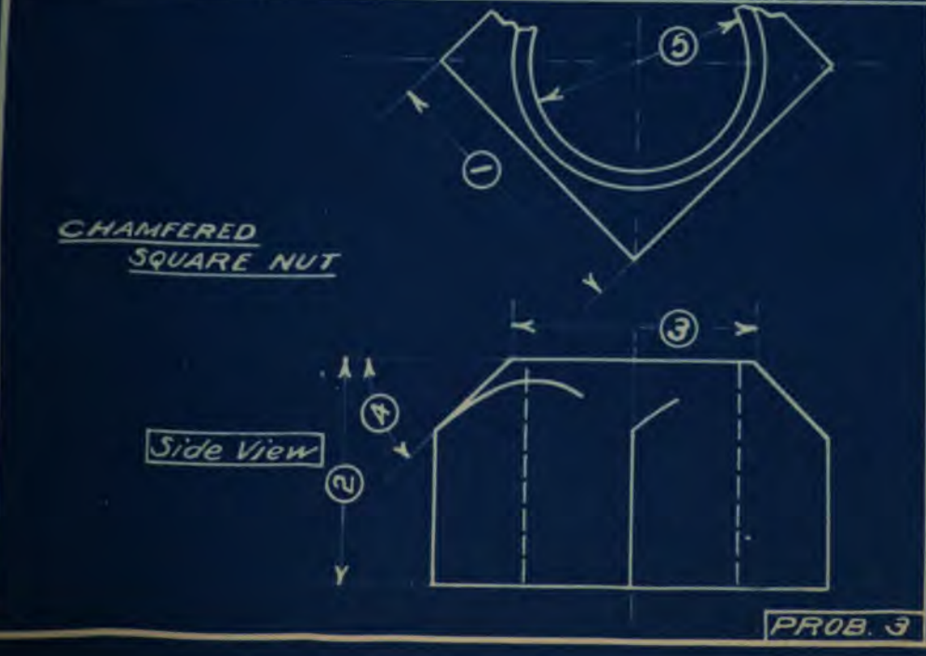
IV. Problem 2. Intersection of *Sphere and Hexagonal Prism.*
Nuts made thus are said to be "**rounded.**"

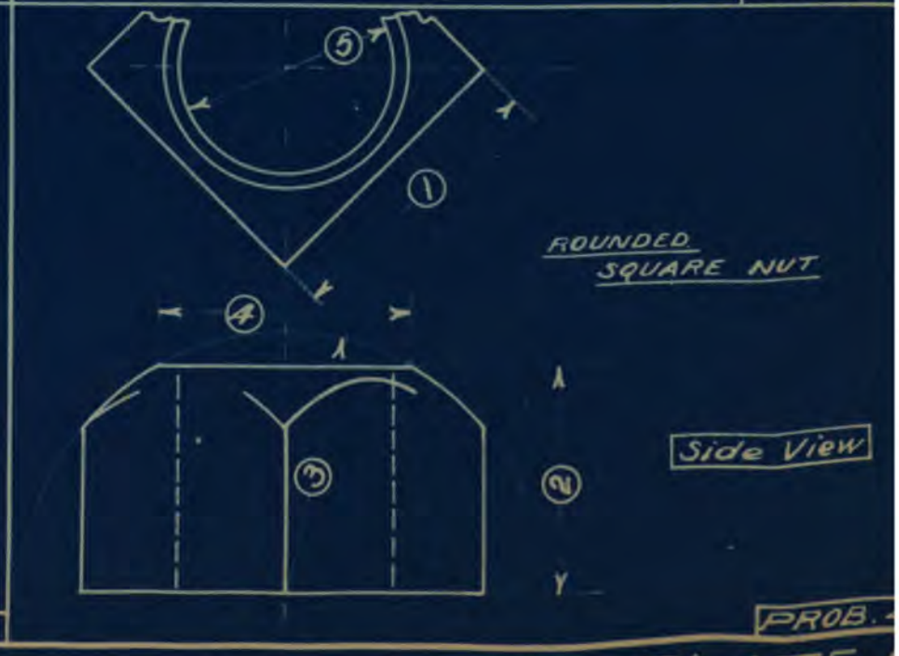
V. Problem 3. Intersection of *Cone* and *Square Prism.*

VI. Problem 4. Intersection of *Sphere* and *Square Prism.*


CHAMFERED
HEXAGON NUT
Hyperbola
Side View
PROB. 1


ROUNDED
HEXAGON NUT
Side View
PROB. 2


CHAMFERED
SQUARE NUT
Side View
PROB. 3


ROUNDED
SQUARE NUT
Side View
PROB.

PLATE

PLATE 17 — INTERSECTION OF SURFACES — DEVELOPMENTS PRISMS, PYRAMIDS, ETC.

LECTURE DATE.....

PLATE 17 — INTERSECTION OF SURFACES — DEVELOPMENTS PRISMS, PYRAMIDS, ETC.

I. Given two Prisms (**I** and **II**), to draw their line of Intersection, and to make a Development of the resulting surfaces. (See Fig. 1 on opposite page.)

II. Method of Constructing Intersection.

(*a*) First block out lightly the three views (**F. V.**, **T. V.**, and **L. V.**) of both prisms, without regard to their intersection. The edges are indicated by letters **a, b, c,** etc.

To construct Prism **II** it will be found necessary to draw first an "End View" (**E.V.**) — looking in direction of arrow **R**.

(*b*) In turn consider each edge of one prism as intercepted by a *side* of the other, and locate the point where that edge terminates.

In **T.V.*** the edge **n** of Prism **II** is intercepted at point **1** by the side **ab** † of Prism **I**. This point **1** can now be identified in **F. V.** and **L. V.** *on the same edge* **n**.

To find the point where the edge **b** of Prism **I** pierces the side **np** † of Prism **II**, we must first insert in this side a *Surface Line* which will meet edge **b**.

Such a *Surface Line* is **S. L.** parallel to the edges **n** and **p**. It is located first in **T.V.** and then identified in **E.V.** by distance **A**, and in **F.V.** by point **X**.

The intersection of Surface Line **S. L.** and edge **b** in **F.V.** gives desired point **2**, which can then be located *on same edge* **b** in **L.V.**

(*c*) Points on the other edges can be found similarly and joined in the proper order to give the required Intersection, **1–2–3–4–5–1.**

III. The Development of the surface of each Prism is built up by transferring true lengths as in Plate 12.

The Surface Line **S. L.** is here again useful in locating point **2** in the Development of Prism **II**. See distances **F** and **G**.

* The point where the *side* intercepts the *edge* is first found in a view where the side appears *edgewise* as a straight line.

† The two edges which bound a side serve conveniently to designate the plane surface of the side between them.

PLATE 18 — INTERSECTION OF SURFACES — DEVELOPMENTS CYLINDERS, CONES, ETC.

LECTURE DATE.....

PLATE 18—INTERSECTION OF SURFACES—DEVELOPMENTS CYLINDERS, CONES, ETC.

I. Given two cylinders, **I** and **II**, to draw their line of intersection and to make a Development of the resulting surfaces.

II. Method of constructing *Intersection.*

(*a*) General method similar to that of the previous plate, "surface lines" (**a, b, c, d,** etc.) being required as in the case of the intersection of *plane* and *cylinder.* (See Plate 14, Pages 56 and 57.)

Surface Lines **may be taken at will, but for convenience in drawing the Development of Cylinder II it is best to space them at equal intervals in E.V.**

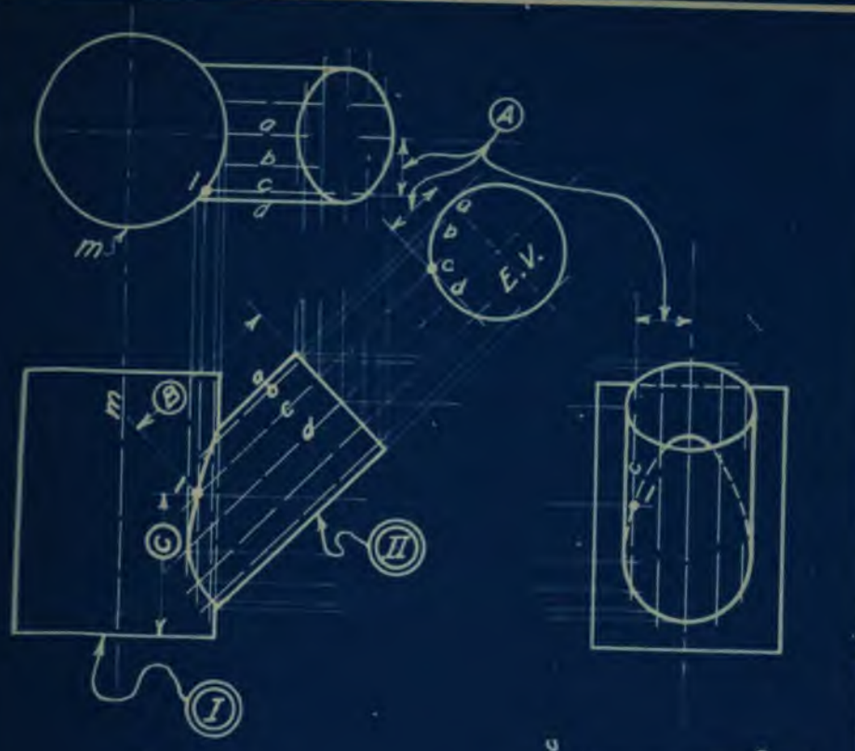
The E.V., showing the *true size* of cross-section of the small cylinder, is necessary in order to obtain the T.V. and R.V., and is most conveniently placed as indicated on the blue print.

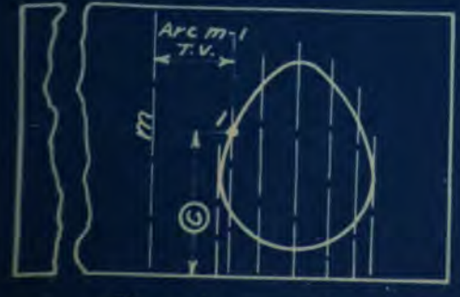
(*b*) In **T. V.** surface line **c** is intercepted by cylinder **I** at point **1.** This point **1** can then be identified in the other views on the same surface line **c.**

(*c*) A sufficient number of points on other surface lines can be similarly found and joined to give a smooth curve of intersection.

III. The *Development* of each cylindrical surface is drawn by locating successive surface lines and identifying points on them. (See Page 57, Fig. 1.)

In constructing Development of II locate surface lines by laying off length of circumference from E.V. and dividing into proper number of parts.





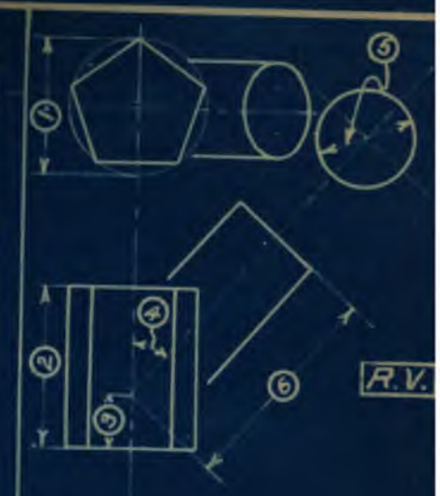
Development of I

Development of II.

FIG. 1

Developments

PROB. 1



Developments

PROB. 2

Developments

PROB. 3

Developments

PROB. 4

PLATE 19—ISOMETRIC DRAWING

LECTURE DATE.....

I. **Isometric Projection or Drawing** is a method of showing, *in one view*, what in *Orthographic Projection* requires two or more views. It resembles a distorted *Perspective Drawing*.

II. Example: **Rectangular Block.**

(*a*) Fig. 1. = Orthographic Projection of block, only *one* face of which is seen in any view.

(*b*) Fig. 2. = Orthographic Projection of block, so turned on its base that *two* faces are seen in Front View ($\theta = \theta'$).

(*c*) Fig. 3 = Orthographic Projection of block tipped up from the horizontal so that *three* faces are seen in Front View, the edges **W**, **D**, and **H** being foreshortened. When the tipping is such as to foreshorten these three edges in the same proportion, the resulting Front View is called **Isometric Projection.***

The above result occurs when $\beta = \beta' = 30°$ and $\phi =$ about 35°. The foreshortened edges (**W**, **D**, **H**) will then be .816 times their true length.

In practice this foreshortening is disregarded and the edges are drawn in their true lengths. The view thus made is usually called an **Isometric Drawing** to distinguish it from the exact **Isometric Projection** above described.

III. **Construction of an Isometric Drawing.** (Figs. 4 and 5.)

(*a*) A simple drawing of the object in Orthographic Projection is first made as in Fig. 4. On this the three mutually perpendicular axes corresponding to the usual *three dimensions of space* may be called *Width* (**W**), *Depth* (**D**), and *Height* (**H**) respectively.

(*b*) In the *Isometric Drawing* (Fig. 5) the two axes **W** and **D** are represented by lines at 30° with the horizontal, while the **H** axis remains vertical.

(*c*) After these axes have been drawn in the new position, every point of the object is transferred from the Orthographic Projection to the Isometric Drawing and placed in the corresponding relative position with respect to the three axes.

To do this, coördinate distances to each point, measured *parallel to the axes*, must be transferred to the Isometric Drawing and laid off parallel to the same axes.

For instance, point **2** is located by distances **A** parallel to the **D** axis, and **B** parallel to the **W** axis.

It will be seen that any line originally parallel to any one of the three axes in *Orthographic Projection* becomes parallel to the same axis in the *Isometric Drawing* and will there appear in its true length. Hence such lines can be laid off at once. (See Distance **E** for line **6–7**.)

(*d*) Locate all the *points* of the object and join them consecutively to make the outline of the object as shown.

Questions for Consideration

(1) Are there any lines which appear in the Isometric Drawing *longer* than their real length?

(2) If so, how do you explain the fact?

* Other kinds of Projection are in use, called by various names according to the assumed amount of tipping and the consequent extent to which the edges are foreshortened. The method of construction is similar to that here explained.

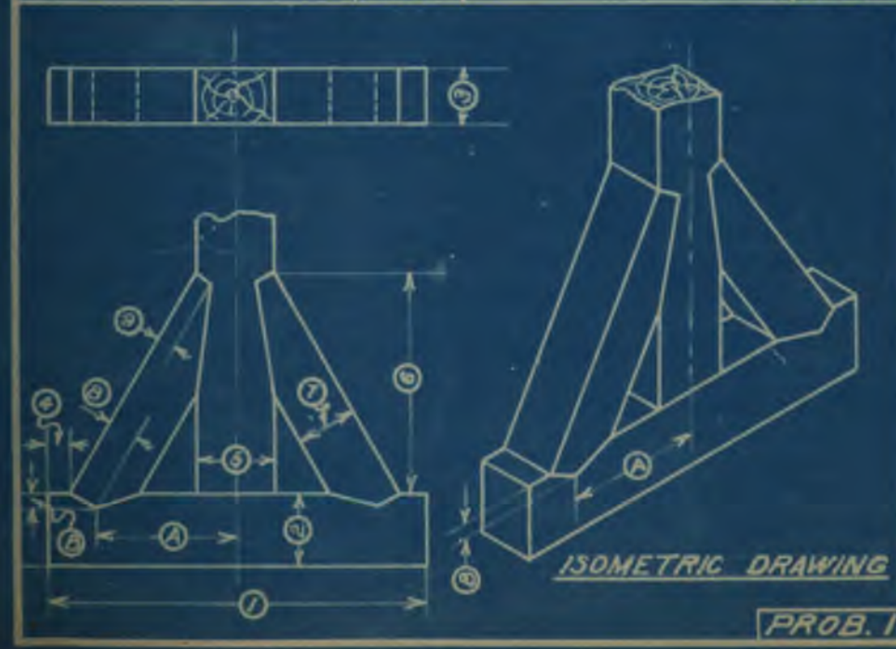
FIG. 1

FIG. 2

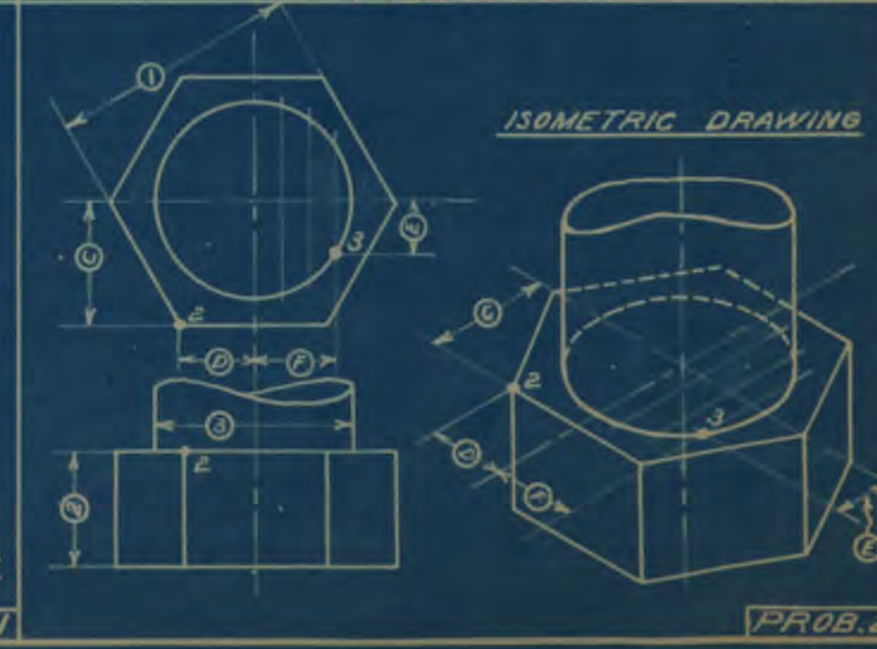
FIG. 3

FIG. 4

FIG. 5



PROB. 1



PROB. 2

PLATE 10

LECTURE DATE

I. A **Helix** is defined as the path traced by a *point* which rotates *around* an axis while, at the same time, it moves *parallel* to that axis.

To see this clearly, two views must be taken; the *Top View* (see Fig. 1) showing the rotary movement in the circle **0-1-2** etc., and the *Front View* showing the movement *upward* parallel to the axis. The curve in *Front View* is the "projection" of the Helix.

The distance (upward) parallel to the axis which the point covers while making one revolution is called the "**Pitch.**" If both movements are uniform (as is generally assumed) the position of a point on the curve may be expressed by the equation: —

$$\frac{\mathbf{A}}{\mathbf{P}} = \frac{\theta^\circ}{360^\circ}.$$

II. A **Helical Surface** is generated by a moving **line**, each end of which lies in a Helix.

For instance line 4–4′ terminates in Helices **1** and **2** respectively in Fig. 1.

Note (in *Front View* above the "Meridian Line," **6–6′**) the position of the generating line **x** before it disappears from sight behind the surface. As it does so, it leaves a profile which is seen as a very flat curve. (See position **y**.) This curve can be approximately represented by a straight line drawn tangent to the two Helices. (See line **t–t′** in Fig. 2.)

III. Springs, Screw Threads, etc. (like those given in the problems on opposite page) are applications of *Helical Surfaces* in practice.

IV. **Suggestion for Problems.**

It is best first to draw lightly the "**Meridian Outline**" for the whole length of each thread (and for the Nut) before constructing any of the required Helices.

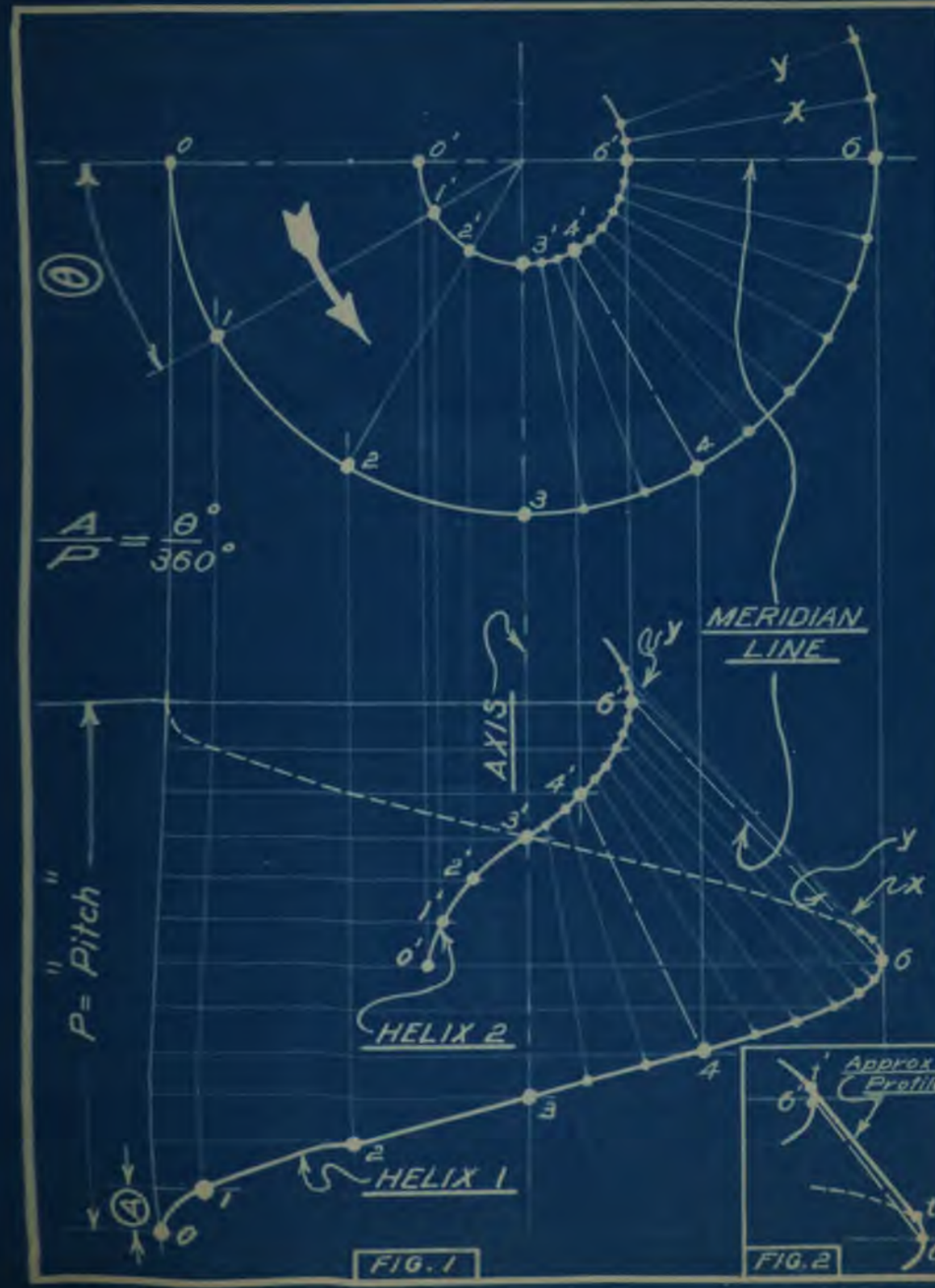
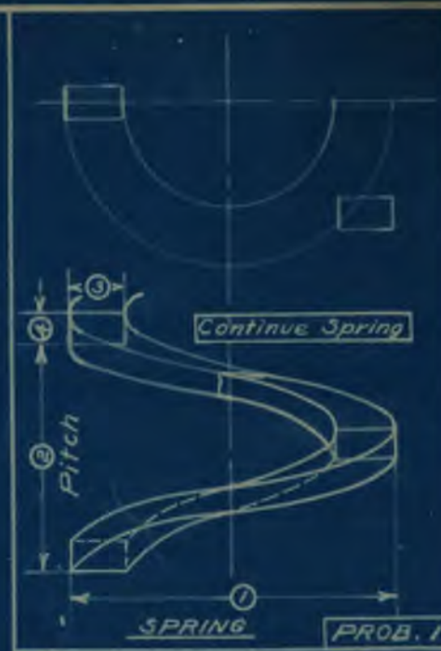
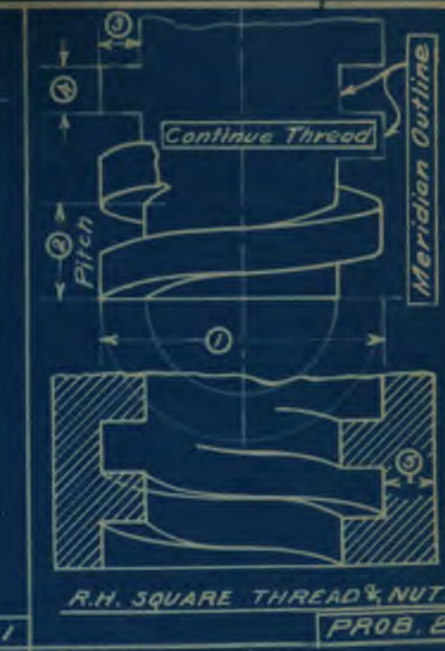


FIG. 1

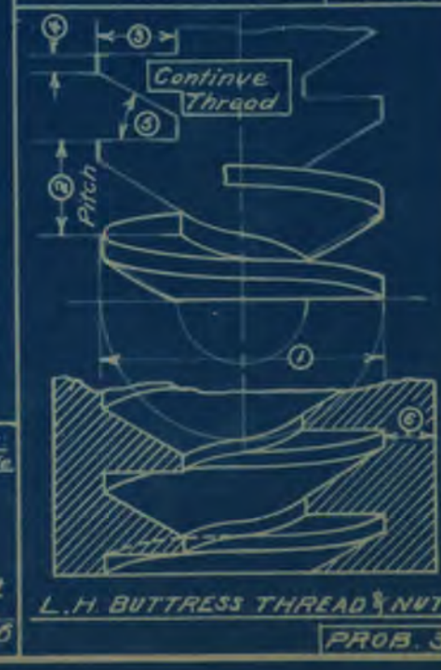
FIG. 2



PROB. 1



PROB. 2



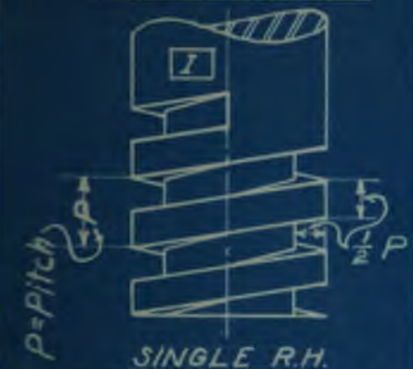
PROB. 3

PROB. 4

PLATE 20

—CONVENTIONS—

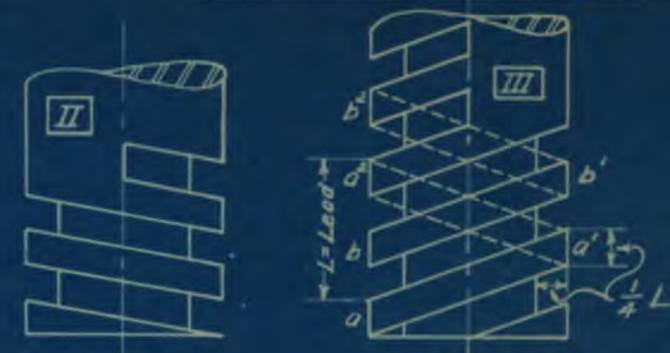
SQUARE THREAD First Method



SINGLE R.H.

Diom.= ①
Pitch = ②

SQUARE THREADS Second Method



SINGLE L.H.

Diom.= ①
Pitch = ②

DOUBLE R.H.

Diom.= ①
Lead = ②

TRIPLE L.H.

Diom.= ①
Lead = ②

SPRING

Upper part = section thru centre of spring

"V" THREADS First Method

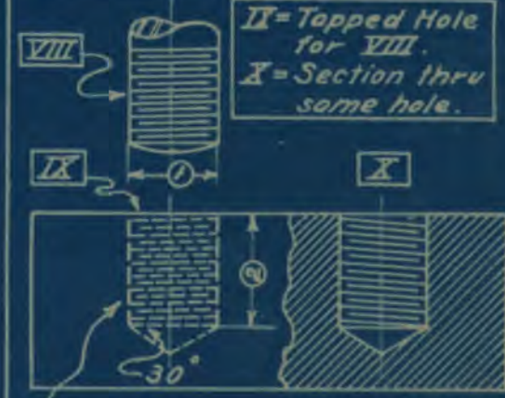
SINGLE R.H.

Diom = ①
Pitch = ②

DOUBLE L.H.

Diom = ①
Lead = ②

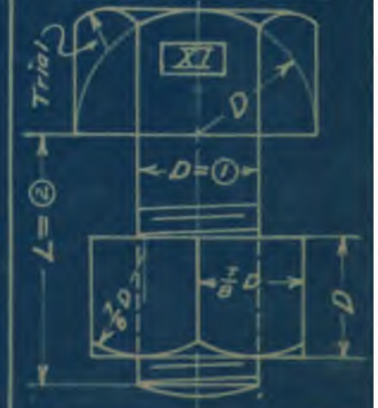
"V" THREADS Second Method



VIII = Tapped Hole for VIII.
X = Section thru some hole.

Space slanting lines by eye alone.
Depth ② = about 1½ X Diom ①.

BOLT AND NUT

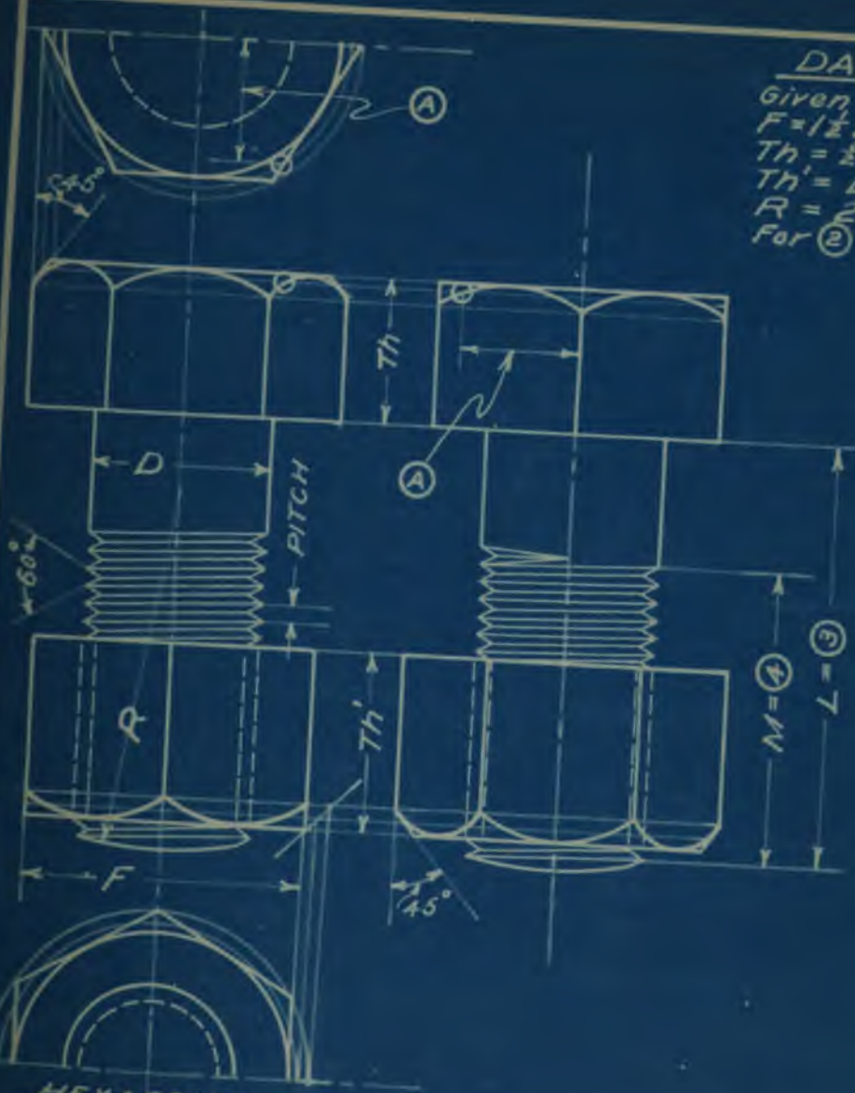


See Page 103 VI.

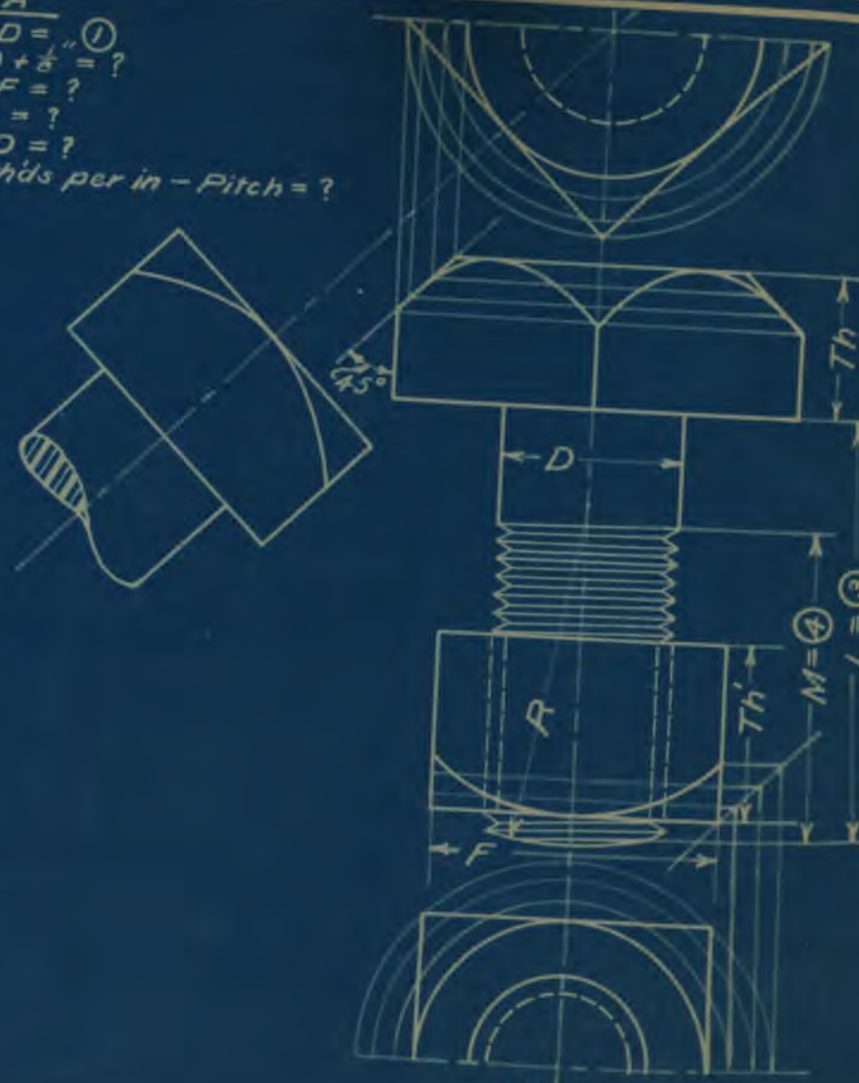
NOTE: (a) R.H. = Right Hand. L.H. = Left Hand.
(b) "First Method" is slightly conventionalized and may be used on Large Threads.
(c) "Second Method" is freer convention used on Small Threads.
(d) Other conventions for small V threads sometimes used are :

DATA

Given D = "①
F = 1½D + ⅛" = ?
Th = ⅝F = ?
Th' = D = ?
R = 2D = ?
For ② thds per in – Pitch = ?



HEXAGONAL



SQUARE

PROPORTIONS FOR STANDARD BOLT AND NUT.

NOTE: (a) Bolt thus made in shop according to a common standard—"United States."
(b) Method of drawing a hex. nut often simplified as in PAGE 103 – VI.
(c) For no. of threads per inch (standard for given diam.) see table on PAGE 103 – I.
(d) To specify a bolt, only dimensions ...

See Pages 60 & 61

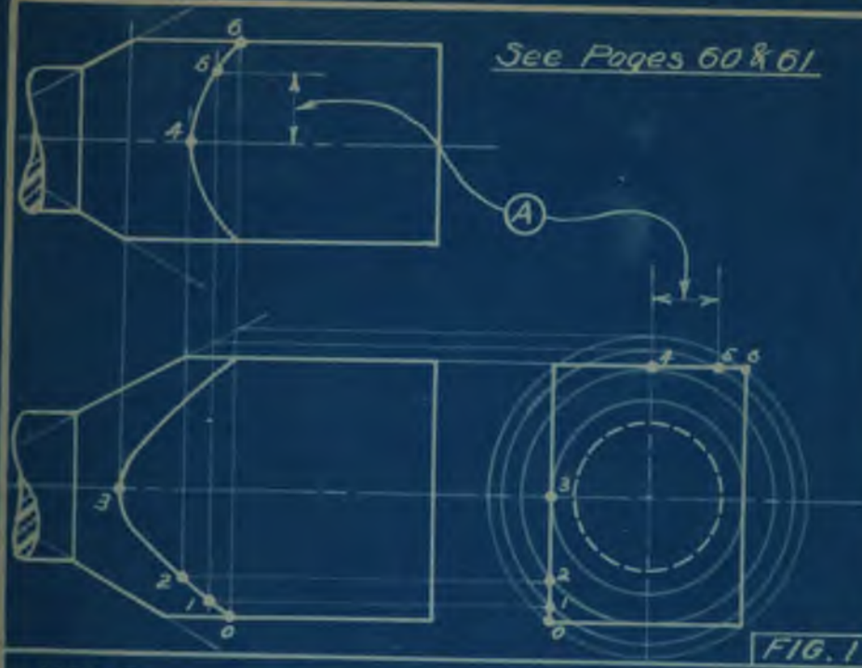


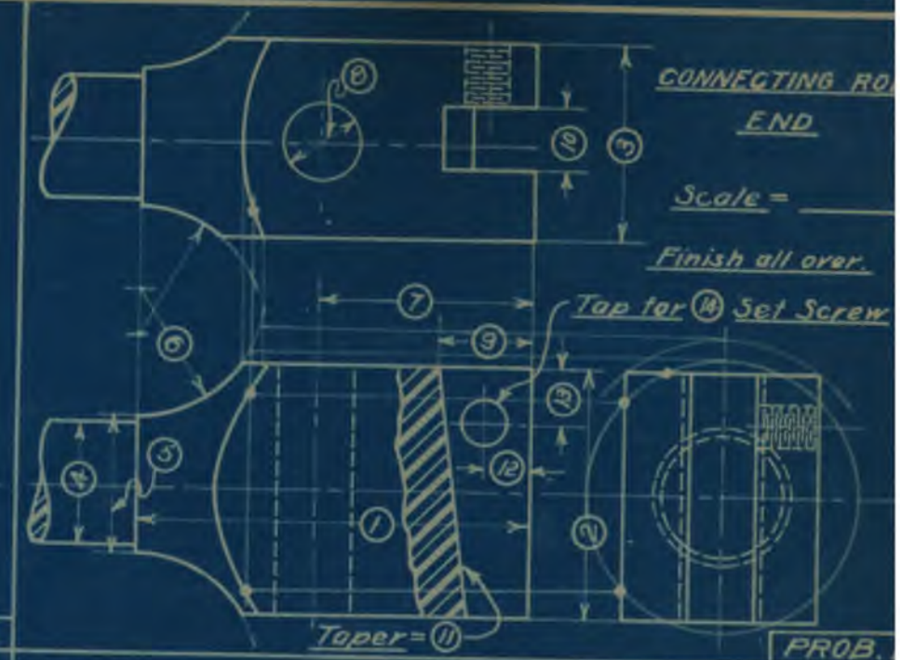
FIG. 1

CONNECTING ROD END

Scale =

Finish all over.

Tap for (14) Set Screw



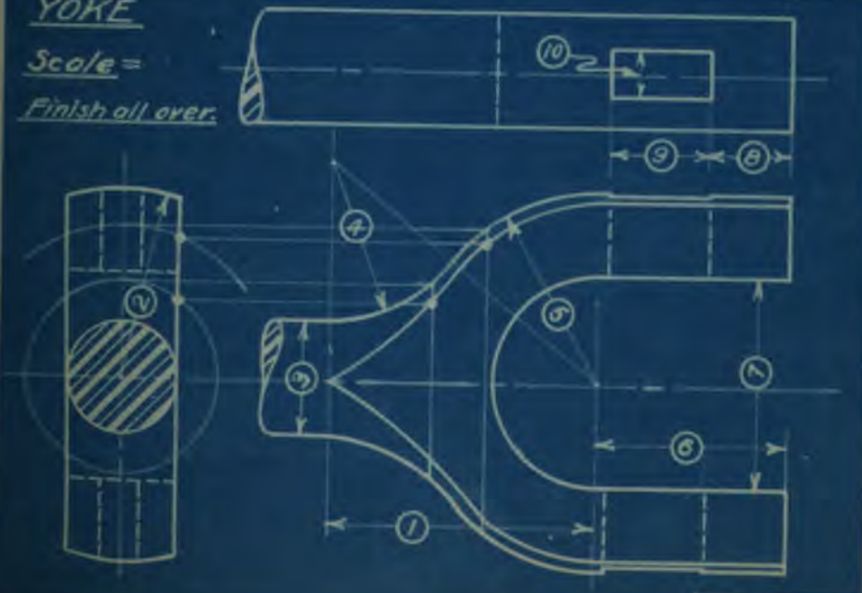
Taper = (11)

PROB.

YOKE

Scale =

Finish all over.

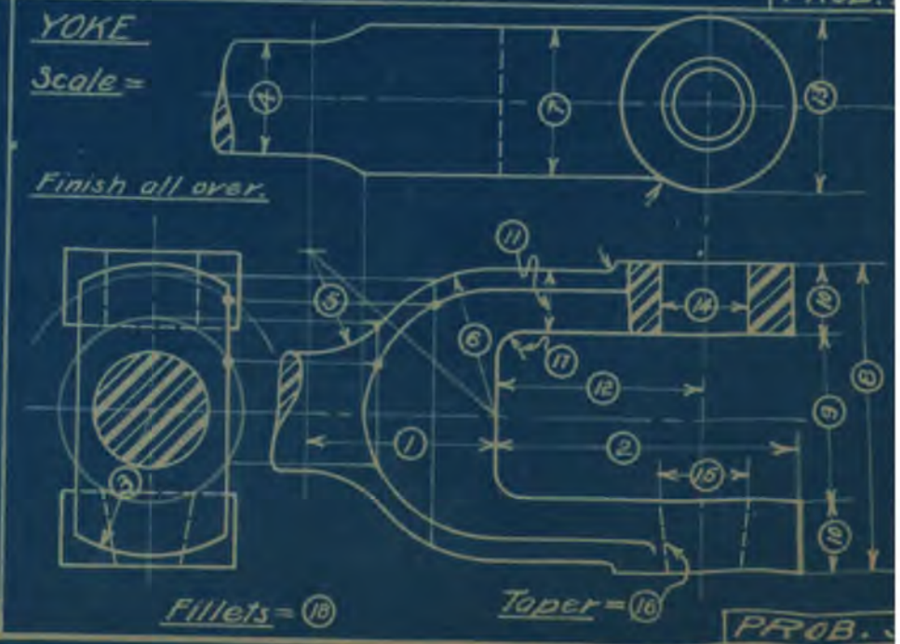


PROB. 2

YOKE

Scale =

Finish all over.

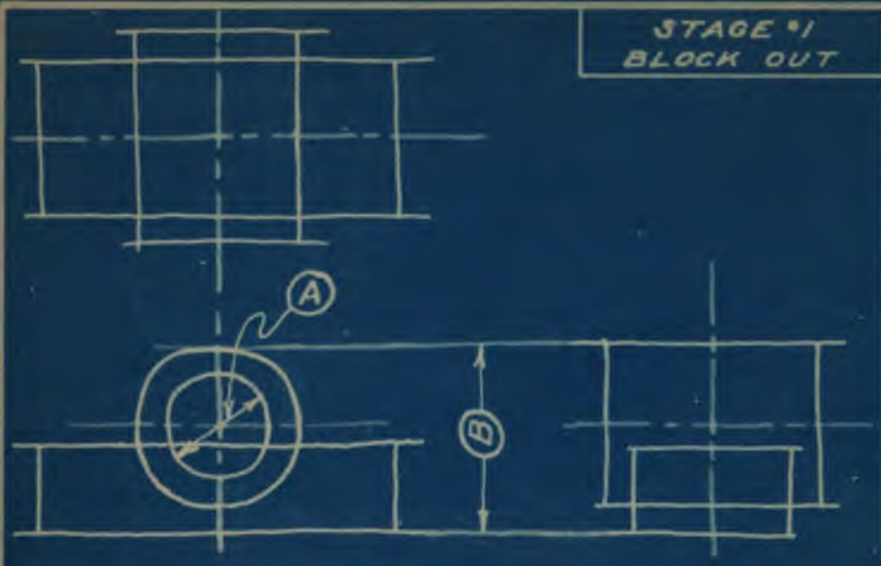


Fillets = (18)

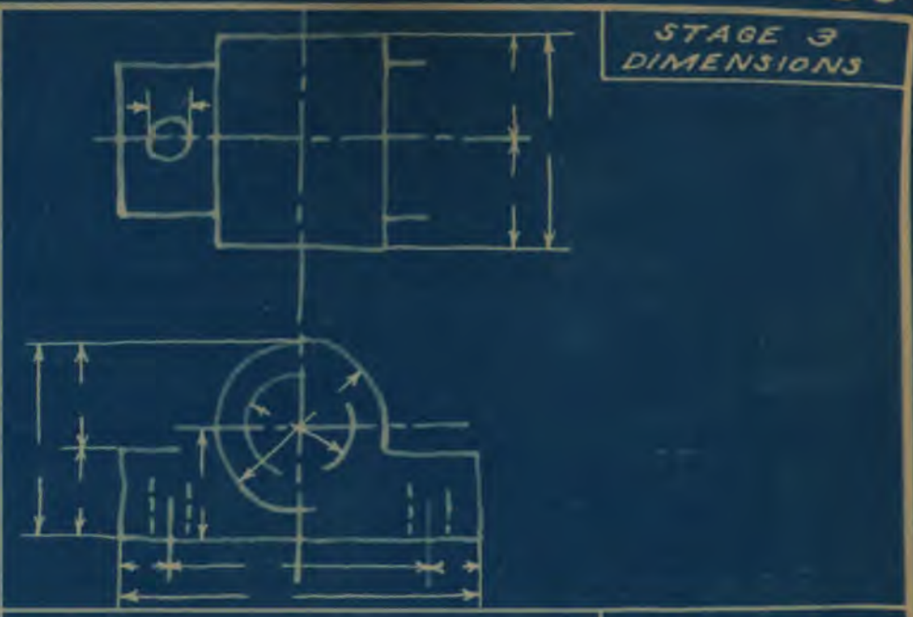
Taper = (16)

PROB.

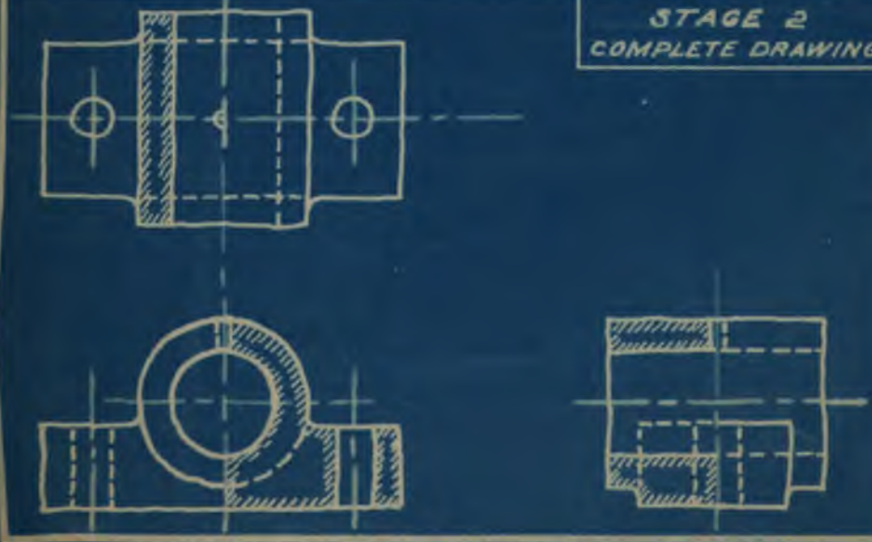
STAGE 1
BLOCK OUT



STAGE 3
DIMENSIONS



STAGE 2
COMPLETE DRAWING



(1) Insert figures in dim. lines.
(2) Add "f" to denote those surfaces which are to be machined.
(3) Add any notes, as:—
(4) Title thus:

SHAFT BEARING
One wanted – C.I.

STAGE 4
FINISH

"C.I." = Cost Iron.

ORDER OF PENCILING FOR FREEHAND SKETCHES.

(a) Draw directly from model, not estimating actual lengths in inches but judging proportions of one part to another. Thus: B = about 2 A, etc.
(b) Dimension Figures (Stage 4). Each student will design actual sizes following proportions of the model. The diameter of the Shaft will be given.

PLATE 24

PLATE 25 — PREPARATION OF A WORKING DRAWING

SUBJECT — ENGINE CRANK

LECTURE DATE.....

PLATE 25 — PREPARATION OF A WORKING DRAWING

SUBJECT — ENGINE CRANK

I. **Freehand Sketch.**

(*a*) The different parts of the Crank are to be "**detailed**" carefully *freehand* on Sketching Pad.

(*b*) Draw directly from the object, judging proportions *by eye alone.*

(*c*) Follow stages.

1. *Block out* views of all the parts, so as to gauge the best arrangement of the entire sheet. Draw as many views of each part as seem necessary.
2. *Complete outlines,* ready for dimensions. (Then correct your drawing by comparing with large sheet posted in drawing room.)
   Show sections as indicated.
3. Draw *dimension lines.* (Use red pencil — *lightly.*)
4. Finish.
   (*a*) Dimension figures. (Measuring crank with two-foot rule and calipers.)
   (*b*) Statements and shop specifications, including "*finish marks.*" (See Note **B.**)
   (*c*) Brief title giving name of object, and the material and number wanted.

II. **Pencil Drawing.**

(*a*) An "**assembly**" drawing (showing parts fitted together) is to be made with instruments on Duplex paper, following usual sequence of stages.

Choose your own set of views, consulting those given as suggestions on opposite page. (See Note **A.**) After choosing and blocking out views, submit to an instructor for discussion of merits of the choice.

(*b*) Lettering.
   (1) Shop specifications.
   (2) Bill of Material and Witness Marks. (See Note **C.**)
   (3) Formal title (given on opposite page) in *lower right hand corner* of sheet.

(*d*) Correct carefully but do not put check marks on this sheet. Sheets will be exchanged and checked later when notice is given.

III. **Tracing.**

Note A. Choice and Arrangement of Views.

1. Select for **Front View** that one which gives clearest idea of object.
2. If possible place **F. V.** to show object in its *natural position.*
3. Select views which show important lines *full* rather than *dotted.*

   Note. — Hidden lines (dotted) should be drawn when they add to the general clearness of the drawing.

4. Draw as many other views as are necessary to show the object clearly.
5. Arrange all views about **F. V.** in accordance with the principles of Orthographic Projection given on earlier sheets (*i.e.* **T. V.** above; **B. V.** below; **R. V.** at right; etc.). This is the usual practice in the United States.

   To avoid confusion, hold object stationary and imagine your own standpoint changed for each view, instead of turning the object itself.

Note B. Shop specifications amplify the information given by dimensions: for instance, the definition of the greater degree of tightness implied in "shrink fit" for the Pin than in "driving fit" for the Shaft. **Finish marks** (see Page 101 — IV) indicate which surfaces of a casting are not left rough as they come from the mold but are machined to a smooth surface. Denoted by — "**f**" — in some view where the surface can be seen edgewise as a straight line.

Note C. The **Bill of Material** (see opposite page) is a list of all the parts with certain information about each one. The **Witness Marks** (first column), though not always shown, help to identify parts, especially when there are several on the sheet, or when a part has no commonly used name.

B.V. = Bottom View.

FIG. 9

BILL of MATERIAL

FIG. 10

MARK	No WANTED	NAME	MAT'L	REMARKS
A	1	Face	C.I.	
B	1	Pin	Steel	Finish all over
C	1	Shaft	W.I.	Finish all over
D	1	Key	Steel	3/8" x 3/4" x 1 1/4" fitted.

FIG. 11

This title will be used on Machine Drawings (except freehand). Frame 4" x 2"

TITLE

ASSEMBLY OF
ENGINE CRANK
Scale: Date
Eng'g 3a—Sheet ?
John Harrard '12

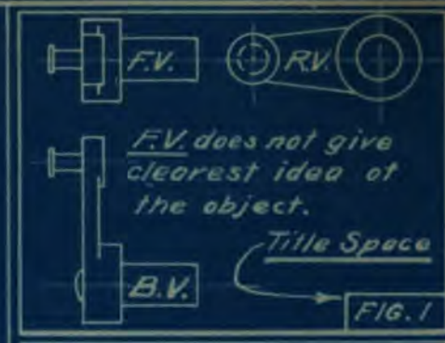


FIG. 1

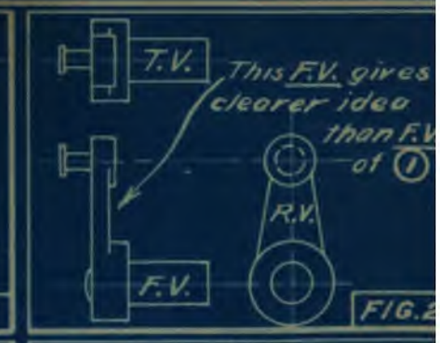


FIG. 2

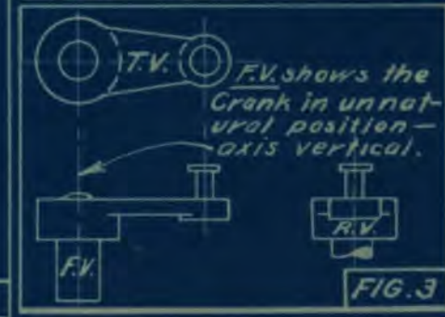


FIG. 3

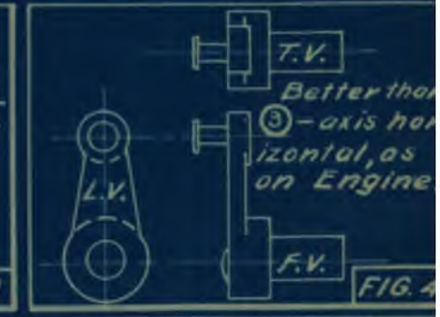


FIG. 4

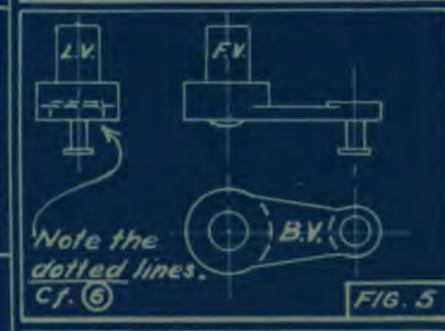


FIG. 5

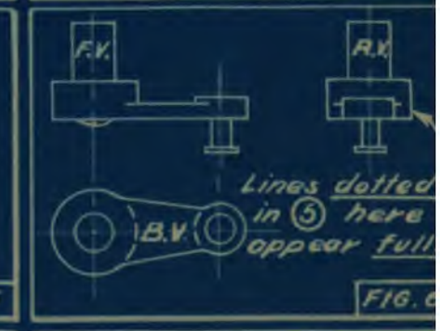


FIG. 6

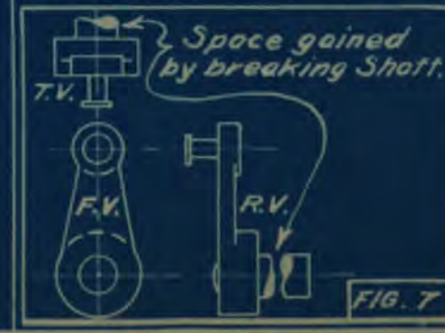


FIG. 7

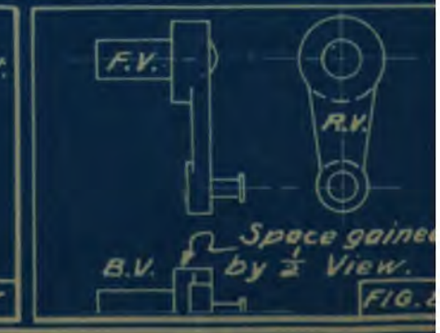
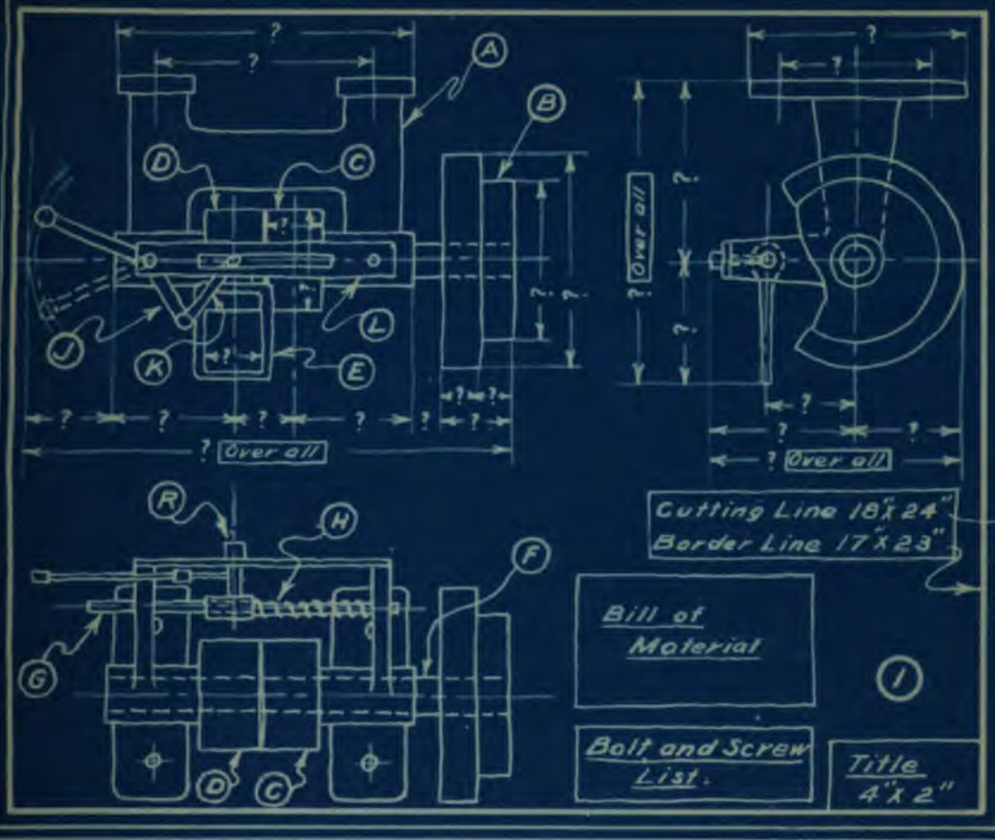


FIG. 8

PLATE 2



BILL OF MATERIAL. (2)

MARK	NO WANT'D	NAME	MAT'L	REMARKS
A	1	Frame	C.I.	
B	1	Cone Pulley	C.I	with Set Screw M
C	1	Tight Pulley	C.I.	" " " N
D	1	Loose Pulley	C.I.	with Oil Hole
E	1	Shifting Yoke	C.I	
F	1	Shaft	Steel	Finished Bright
G	1	Shifter Rod	W.I.	
H	1	Spring	Brass	#13 Wire B&S.
J	1	Bell Crank Lever	W.I.	J&K connected
K	1	Link	W.I.	by Rivet O
L	1	Guide Plate	W.I	

BOLT AND SCREW LIST. (3)

MARK	NO WANT'D	DESCRIPTION	MAT'L	FOR
M	1	$\frac{3}{8}$" X $\frac{1}{2}$" Set Screw	Steel	Cone Pulley
N	1	$\frac{3}{8}$" X $\frac{5}{8}$" Set Screw	Steel	Tight Pulley
O	1	$\frac{1}{4}$" X $\frac{3}{8}$" Rivet	W.I.	Link
P	1	$\frac{3}{8}$" X $1\frac{5}{16}$" Cap Screw	W.I.	Guide Plate
Q	1	$\frac{3}{8}$" X $\frac{11}{16}$" Cap Screw	W.I.	Guide Plate
R	1	$\frac{3}{8}$" X $1\frac{3}{16}$" Bolt	W.I.	Yoke

COUNTER SHAFT

I. "DETAIL" DRAWINGS (Freehand on Sketching Pad).

(a) Follow stages as on Page 89. See also Page 92.

(b) Draw from model as far as possible, using posted drawings only as guide.

(c) Dimension figures: Copy those posted. For all others, marked "?", measure model with Two-foot Rule and Calipers.

II. "ASSEMBLY" DRAWING (in pencil with instruments).

(a) Size: 18"x24" with $\frac{1}{2}$" Border inside. (See (1) above).

(b) Preliminary layout first drawn (free hand on Sketch Pad) to plan arrangement of Assembly sheet. Position of Views, Title, etc. suggested by rectangles drawn roughly to scale. Adjust spacing for good appearance of sheet.

(c) Dimensions: Only those indicated in (1) above; i.e. - those giving general information of use to assembler, erecter, buyer, etc.

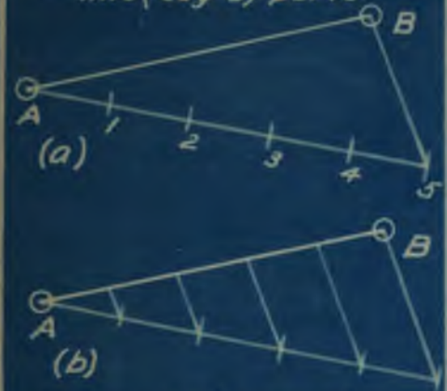
(d) Title: 4"x2" Standard form given on Page 93.

III. TRACING (See Pages 31 and 32). To be "Checked" when completed.

IV. BLUEPRINT.

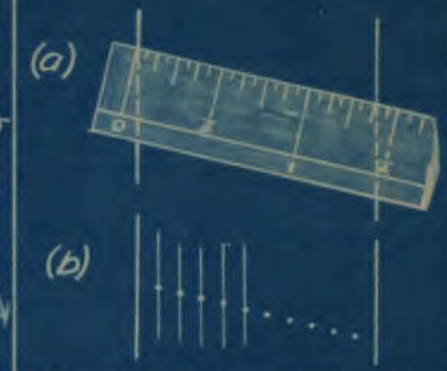
24

(1) To divide a line AB into (say 5) parts.



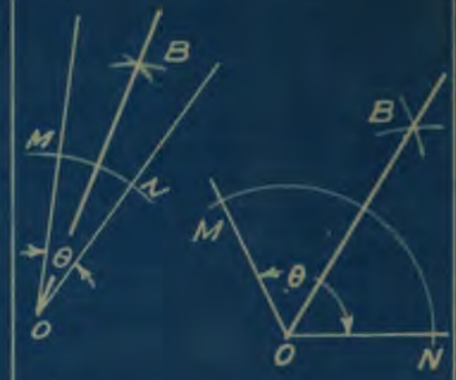
(a) 5 spaces (any size) on A5 (any line). Join 5B
(b) Lines parallel to 5B give required divisions.

(2) To divide a space into (say 11) parts for parallel lines.



(a) Point off 11 units (any size) with scale aslant.
(b) Draw parallel lines.

(3) To bisect an angle θ.



(1) Arc MN = any radius.
(2) Arcs at B = centres at M and N.
(3) OB = Bisector.

(4) To erect a perpendicular to AB at P.

(1) S = any point.
(2) Circle thru P. (S = centre)
(3) CD thru S.
(4) PD = required perpendic

(5) To draw a tangent to a circle from a point P.

(1) Semi-circle on PC, (A = centre)
(2) PT = required tangent.

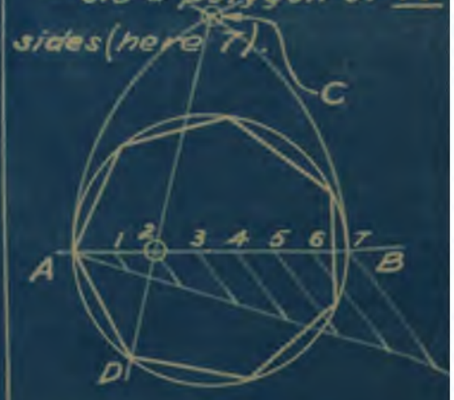
(6) To draw an arc tangent to 2 given circles, #1 and #2. Given R_1, R_2, and R_3.

(1) Arcs from A & B meet at O.
(2) O = centre of required tangent arc.

(7) To pass an arc thru 3 points A, B, and C.

(1) Join AB & BC with str't lines.
(2) ⊥'s at middle pt's meet at O.
(3) O = centre of arcs.

(8) To inscribe in a circle a polygon of N sides (here 7).



(1) Divide AB into N parts.
(2) Arcs AC & BC (A & B = centres
(3) CD always thru second point
(4) AD = required side.

A IN GENERAL

(1) First dimension that view which shows details most clearly

(2) Avoid repeating dimensions on a second view

(3) Dimension where possible to centre lines and finished surfaces

(4) Place dimensions outside of drawing if confusion would result from placing them inside.

(5) Dimension distances only in those views where they appear in their true length

B SYMBOLS

(1) 9" = 9 inches 13" = 13 inches etc.

(2) 4' or 4'-0" = 4 feet 5'-6" = 5 feet-6 inches

(3) Under 2 ft use inches, above 2 ft use feet and inches.

(4) 3" diam. or 3"d = 3 inches diameter

(5) 3" rad. or 3"r = 3 inches radius.

C CONVENTIONS AND ILLUSTRATIONS

(1) Fractions thus: $\frac{3}{4}$" not thus 3/4".

(2) Arrow Points thus: ← not thus: ← nor →

(3) Extension Lines thus:

not thus:

(4) Arrow Points always to touch lines dimensioned thus:

not thus:

(5) Arrow Points always opposite thus: ←→ or →← not thus: ←←

(6) Horizontal Dimensions thus: ← $2\frac{5}{16}$" →

(7) Vertical Dimensions thus:

not thus:

nor

ie. (Vertical Dimensions to read from RIGHT.)

C CONVENTIONS AND ILLUSTRATIONS cont.

(8) Slanting Dimensions thus:

(9) Small Dimensions thus: $\frac{3}{32}$" or thus $\frac{1}{16}$"

(10) Avoid using LINES or DRAWING or CENTRE LINES as Dimension Lines.

Correct thus:

not thus

(11) Diameters thus:

(12) Radii thus: (only one arrow)

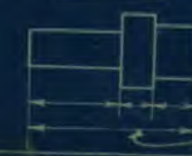
(13) Carry Dimensions where possible along one line.

thus:

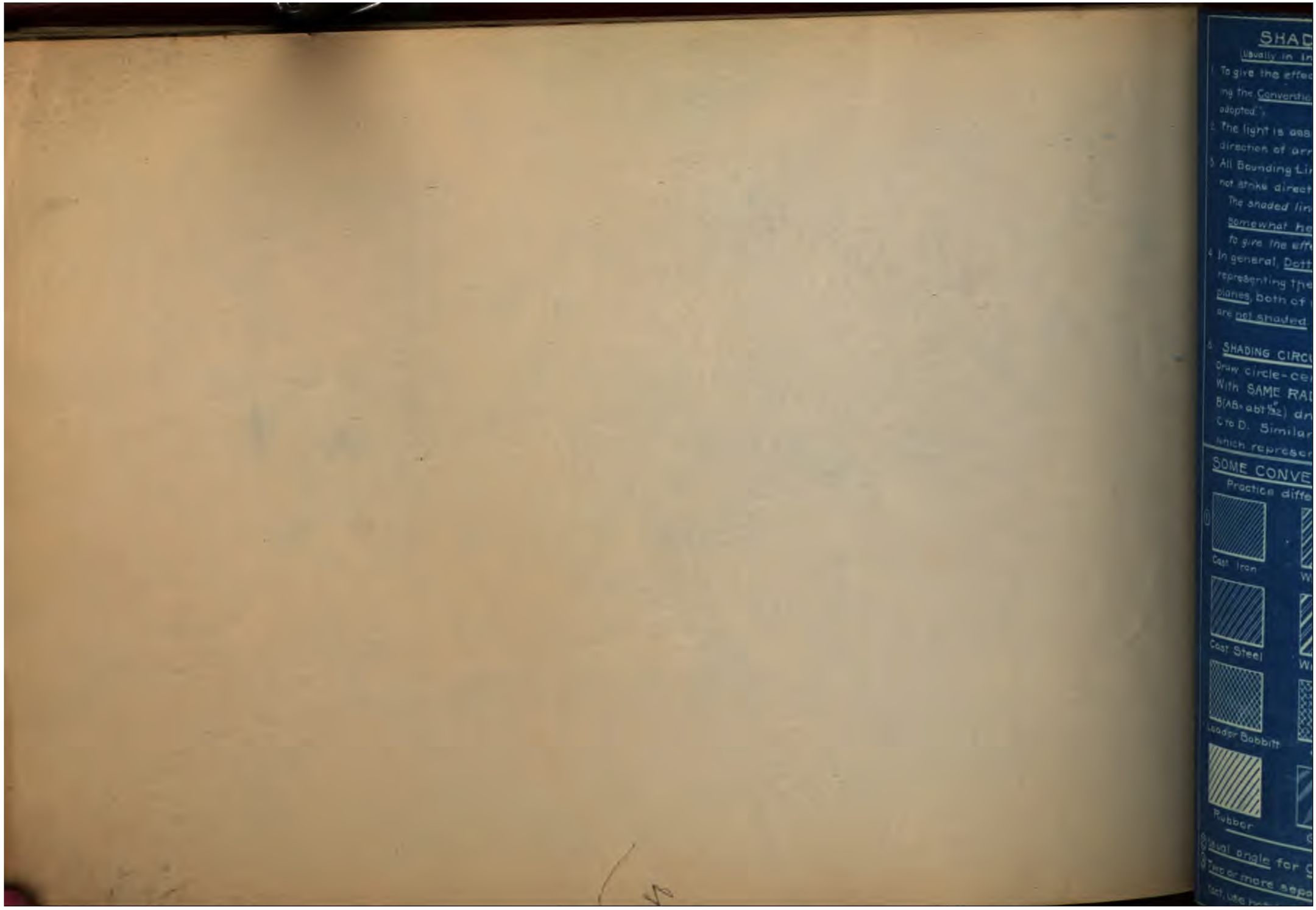
not thus:

(14) Give Dimension "Over All" as well as subdimensions

thus:



(15) Decimal Dimensions thus: 4".06 not ~~.4.06"~~


SHAD
Usually in In
To give the effec
ing the Conventio
adopted.
The light is ass
direction of arr
All Bounding Li
not strike direct
The shaded lin
somewhat he
to give the effe
In general, Dott
representing the
planes, both of
are not shaded.
SHADING CIRCU
Draw circle-ce
With SAME RAD
B(AB=abt 5/32) dr
C to D. Similar
which represen
SOME CONVE
Practice diffe
Cast Iron
Cast Steel
Babbitt
Rubber
qual angle for S
Two or more sepa

U.S. STANDARD FOR V THREADS

Diameter of Screw	Threads per in.	Diam. at root of Thd	Diam. of Tap Drill
1/4	20	.185	3/16
5/16	18	.240	1/4
3/8	16	.295	5/16
7/16	14	.344	23/64
1/2	13	.400	13/32
9/16	12	.454	29/64
5/8	11	.507	17/32
3/4	10	.620	5/8
7/8	9	.731	3/4
1	8	.837	27/32
1 1/8	7	.940	31/32
1 1/4	7	1.065	1 3/32
1 3/8	6	1.160	1 3/16
1 1/2	6	1.284	1 9/32
1 5/8	5 1/2	1.389	1 13/32
1 3/4	5	1.491	1 1/2
1 7/8	5	1.616	1 5/8
2	4 1/2	1.712	1 3/4
2 1/4	4 1/2	1.962	1 31/32
2 1/2	4	2.176	2 3/16
2 3/4	4	2.426	2 7/16
		I.	

II

STANDARD PIPE THREADS

Taper of threads = 1/16 on diam per in.

Nominal Size of Pipe	Outside Diam.	Thickness of Metal.	Threads per inch.
1/8"	0.405	.068	27
1/4	0.540	.088	18
3/8	0.675	.091	18
1/2	0.840	.109	14
3/4	1.050	.113	14
1	1.315	.134	11 1/2
1 1/4	1.660	.140	11 1/2
1 1/2	1.900	.145	11 1/2
2	2.375	.154	11 1/2

III

U.S. STANDARD BOLTS AND NUTS

HEXAGONAL

Chamfered

Rough
F = 1 1/2 D + 1/8"
C = F x 1.15
Th = 1/2 F
Th1 = D

Rounded

Finished
F = 1 1/2 D + 1/16"
C = F x 1.15
Th = 1/2 F
Th1 = D - 1/16"

IV

SQUARE

Chamfered

Rough
F = 1 1/2 D + 1/8"
C = F x 1.41
Th = 1/2 F
Th1 = D

Finished
F = 1 1/2 D + 1/16"
C = F x 1.41
Th = 1/2 F
Th1 = D - 1/16"

V

CONVENTIONAL METHOD

OFTEN USED IN DRAWING SMALL HEXAGONAL BOLTS

Necessary Dimensions = D, L, M.

VI

CONVENTIONAL THREADS

For Large 'V' Threads

For Small 'V' Threads

NOTE! Pitch usually defined as 8 threads per inch, 10 thr. p in, etc.

VII

TAPPED HOLES

THREE METHODS

VIII

BOLTS IN PLACE

IX

STUD BOLT

X

CHECK NUT

XI

LAG SCREW

XII

CAP OR TAP BOLTS

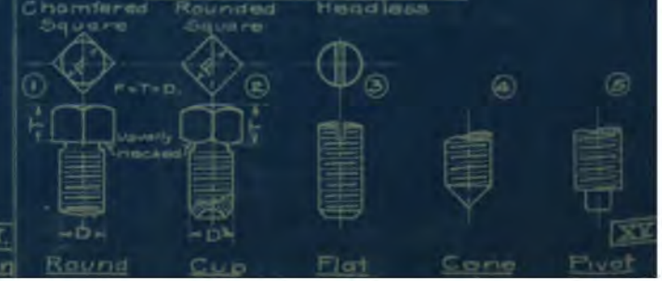
XIII

CAP OR MACHINE SCREWS

XIV

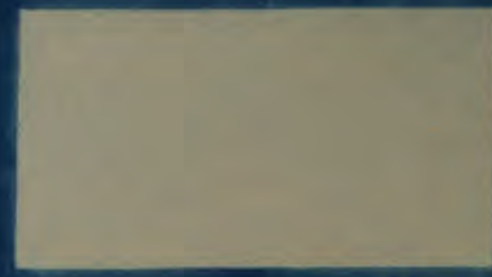
Fillister Round or Flat or Button

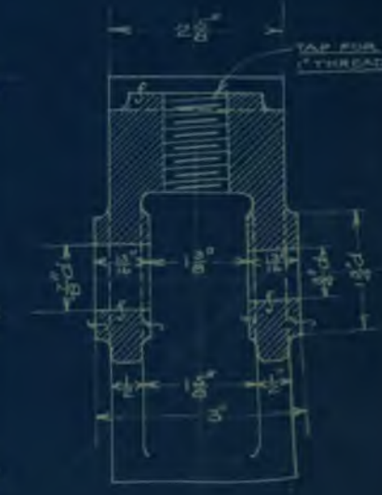
SET SCREWS



XV

SLIDE VALVE





CROSS HEAD

VERTICAL SYSTEM

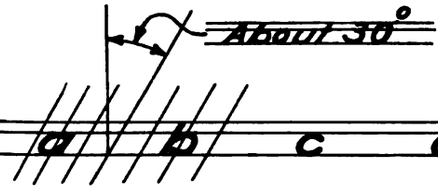
a b c d e f g h i j k l m

n o p q r s t u v w x y z

A B C D E F G H I J K L M

N O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0



SLANTING SYSTEM

a b c d e f g h i j k l m

n o p q r s t u v w x y z

A B C D E F G H I J K L M

N O P Q R S T U V W X Y Z

1 2 3 4 5 6 7 8 9 0

Dimensions thus: 7 5/16" = 3.125 = 6' 9 7/8"

SUGGESTED METHOD FOR MAKING STROKES

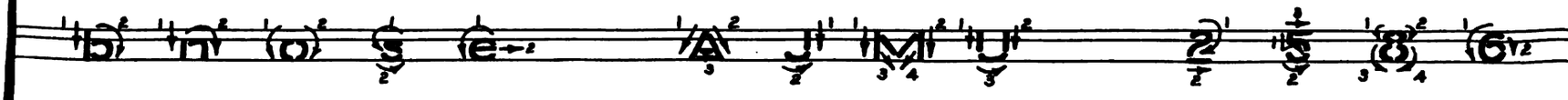


PLATE 32